Giant Lines behind the Lines. This long line of powerful hydraulic presses are equipped with the patented Guerin process. Thick mats of rubber are closely confined within steel walls built around each press ram. Various sizes and shapes of dies lie on the press bed beneath the ram, and sheet metal blanks are placed over them. When the ram descends, the rubber pressure cuts, forms, and draws the blanks into parts for aircraft assemblies. This setup of hydropresses, in Douglas aircraft plant at Santa Monica, Calif., is the largest of its kind in America. (Acme photo.)

Die Engineering Layouts
and Formulas

A reference book illustrating and describing
the key designs of punches and dies
based on precept and formulas

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DIE ENGINEERING LAYOUTS AND FORMULAS

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X

Preface

To succeed in the profession of tool engineering, one must rely entirely upon his accumulated knowledge, experience, and study of the subject. He should have the foresight to recognize a good suggestion, the willingness to adopt it, and the ability to improve and use it. He must be endowed with considerable aptitude for the work, long practical experience, a ready knowledge of applied mathematics, a high degree of the draftsman's speed and skill, and plenty of inventiveness and ingenuity.

A tool engineer must know the details of shop practice—the methods used for setting up different types of work in machine tools; speeds and feeds for cutting different metals; hardening and grinding processes; and the entire mechanical procedure in the fabrication of tools and fixtures, including their design, construction, final assembly, and tryout. He must be able to estimate tool costs, the hourly output of tools, and the total cost of labor and materials for manufacturing multiple parts in mass production. He should be an authority on the subject of tools, and of all the processes used in interchangeable manufacturing.

If a tool engineer can visualize and discover an unusually efficient tool design and foresee all the working conditions, latent possibilities, and collateral operations and is qualified to engineer it through to a successful conclusion, his work is as much of a science as any of the learned professions. Tool engineering requires highly specialized men. It may take 10 or 15 years of experience to become proficient in only a few of its many branches. New materials, machines, and methods of manufacture are constantly being introduced, and one must read and study in order to keep abreast of the times. Modern tool engineering has become so complex that most engineers specialize in only one or two of its various procedures.

Today, in the midst of the Second World War, important changes are unfolding in all the phases of mechanical production and efficiency. Tool engineers are taking a prominent part in these changes. It is a subject of congratulation among them that their profession is beginning to receive some well-deserved recognition from the public. The older tool engineers who at earlier times worked without the aid of

handbooks, tables, or specialized literature, and who traveled the uncertain road of somewhat precarious designing, may be interested to know that many colleges and most universities are beginning to teach the science of tool engineering as a regular part of the annual curriculum.

This book attempts to combine the basic mechanical principles of assembled die designs with their operating details, to give the necessary mathematical formulas for laying out the assembled die, and to emphasize a clearly rendered drafting technique. About four hundred of such drawings and photographs are given. These represent approximately 90 per cent of the key designs used in tools for presswork. Furthermore, some of the more important groups of these key designs have been repeated under a wide variety of different layouts. This procedure serves to impress upon the reader a more comprehensive understanding of all the details involved when designing these types of dies. One example is the many drawings and photographs given for progressive dies and the cut-and-carry types of dies. Progressive dies may be used in blanking and forming parts for small guns; they are also used in fabricating an endless variety of small precision parts used in times of peace.

Many citations refer to the design of tools and dies used for producing war equipment. This inclusion was found necessary at the time this book was written. The critical supply of materials and government priorities referred to will, of course, be entirely released when peace comes again. Fortunately, this does not diminish the usefulness of this book as a guide and reference at any time. The dies shown for war productions and the short cuts explained for drafting them reveal the basic principles of many key designs that will have an endless number of applications after the war.

The forming and drawing of ammunition shells, large cartridge cases, blanking and forming of parts for small guns progressively, and shaping the parts for bomber, fighter, and pursuit planes will naturally be continued in the production of other equipment after the war is closed. The illustrations and descriptions of certain assembly lines, where the work is performed by welding, will be useful in the assembly of truck bodies, household utilities, and agricultural machinery for years to come.

The inclusion of the chapter on welding, which may seem at the moment to depart from the subject of dies, was thought to be necessary because of its close relationship to punch-press work. This will be found true in the production of certain units built up by welding together individual parts made in press tools. The brazing or welding

together of such parts is a method of manufacture often resorted to when necessary to produce certain types of units which would otherwise be impossible to make in any number of individual drawing or forming operatons.

All the die designs illustrated in this book are necessarily centered around the principles set forth in the author's *Pressworking of Metals.* Unlike *Pressworking of Metals,* however, 90 per cent of the die designs presented are working drawings of completed tools. Many of the tools described, or similar ones, could be built from the drawings and dimensions given.

Part of the material has been carefully selected from a few of the author's recently published articles. Therefore, some of the information given in different articles is repeated, but this was found necessary in order to finish each of the descriptions. In addition to the articles, the number of illustrations, photographs, and descriptions has been more than doubled. The many readers who wrote to the publishers of the articles for further information or reprints were referred to the author and answered personally. These inquiries indicated the need for this book.

The author extends thanks and his appreciation to the editors of the following publications in which these articles appeared, for the many business courtesies they extended to him, and especially for their permission to enlarge and use the articles: *American Machinist; Canadian Machinery; Heat Treating and Forging; Machinery; Modern Machine Shop; The Modern Industrial Press;* and *The Tool & Die Journal.*

Special acknowledgments are due *The Modern Industrial Press* and *Heat Treating and Forging* for their excellent renditions of the unusually difficult line cuts published with the articles. The photographs that show recent designs of progressive dies were furnished by the Moore Special Tool Co., and Mr. Richard F. Moore checked the written descriptions of the tools in connection with these pictures. Mr. Moore also made a number of good suggestions on progressive die operations which were adopted.

Valuable assistance, such as furnishing photographs, descriptions, suggestions, or checking of work, was received from the following engineers or their representatives: William M. Nelson, Office of Emergency Management of War Information, Washington, D.C.; Charles C. Misfeldt, Aircraft Engineering Consultant, Glendale, Calif.; M. G. Simpson, Douglass Aircraft Company; Maxwell Stiles, Lockheed Aircraft Corporation; Peter F. Rossmann, Curtiss-Wright Corporation; E. R. Miller, F. J. Littell Machine Co.; M. H. Ivins,

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C. W. Hinman.

Chicago, Ill.,
June, 1943.

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DIE ENGINEERING LAYOUTS AND FORMULAS

CHAPTER I

SHEET METAL ECONOMY IN THE PRESSROOM

Introduction.—The economical utilization of sheet metals in the pressroom has always been a factor of great importance in the press-working of metals. Today, with the critical problem of supply, this subject may even overshadow the types of presses used, the design of dies, and high-speed production. For example, all the advantages gained by running a press at high-speed production may be lost if the scrap is 20 per cent too much.

A job that is highly economical of material, but run on an old-style press with poor equipment, may be more profitable than a wasteful job run on a modern press equipped with the best of tooling designs.

Collaboration.—Unfortunately, in too many metalworking plants there is an apparent lack of friendly cooperation between the engineers of the company's products and the engineers of tool design. Their cooperation is particularly desirable, because it invariably results in preventing excessive tool expense and waste of work materials. Tool designers often discover that, if the shapes of certain piece parts were altered slightly, a far more economical scrap strip could be designed, or a stronger die could be built without expensive inserts. The mutual advantages of this collaboration are so evident that it is really one of the fundamentals of good teamwork. It is also just as important that tool engineers cooperate with the toolroom and pressroom managements, so that all will understand one another's problems.

Substituting Steel for Nonferrous Metals.—The war priority system now in effect has caused an unusual scarcity of most nonferrous metals in private industry, so that it has become necessary to substitute steel for many articles formerly made from aluminum, brass, and copper. This change has proved a profitable one; it can be adopted for many parts in which excessive weight or electrical conductivity is not involved.

Steel parts can be made of lighter gage sizes if there are no forming dies to change. Other steel parts can be reduced to minimum gage thicknesses and then strengthened by stamping them with stiffening ribs, embossings, or concentric designs. Many steel parts can be changed to cheaper grades of steel. For example, auto-body steel can sometimes be substituted for a cold-rolled product. When such changes as these can be made for parts that run into hundreds of thousands of pieces annually, the saving in material and costs is substantial.

Laying Out the Scrap Strip.—It is often tedious work to lay out scrap strips for blanks so as to assure that the maximum percentage of the strip area is used. The procedure is to cut three blank templates from cardboard and arrange them on the drawing board in several experimental positions until, by trial, the most economical arrangement of blanks is found. Comparative areas are determined by multiplying the blanking center distance C by the width of strip S. If the strip contains multiple rows of blanks, the area of one blank is found by dividing $(C \times S)$ by the multiple.

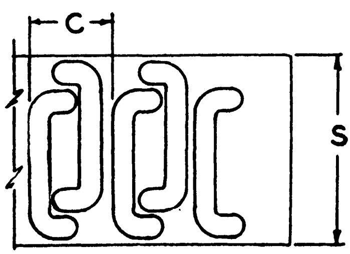


FIG. 1.—The first attempt in designing a scrap strip for a straight blank having "hooked ends."

If the blank is to be subsequently bent or formed, especially with sharp-cornered bends, care must be used in positioning the blanks relative to the grain in the strip. The ideal is to make bends at right angles to the grain, but they can be safely made at an angle of 20 deg. to the grain. The grain direction is usually parallel with the edges of the strip. If this precaution is overlooked, the bends are likely to fracture, especially when they have sharp right-angled corners, and when the gage thickness is heavy.

Scrap-strip Examples Taken from Practice.—In Fig. 1, we have a tentative scrap layout for blanking the U-shaped piece shown within the strip. The shape of this piece is typical. However, a single glance at this layout shows waste. In fact, this layout utilizes less than 50 per cent of the strip.

Figure 2 shows the usual layout employed for blanking pieces of this shape. The appearance of this layout, for economy, looks better than the one shown in Fig. 1. Some die engineers might be satisfied with this because it represents the conventional layout for long pieces with "hooked ends." Nevertheless, this is a wasteful layout since it actually utilizes only 57 per cent of the strip.

Final Determination of the Scrap Strip.—By interviewing the engineer who was responsible for the design of this piece, it was learned that none of the radial arcs was really necessary, since in the final

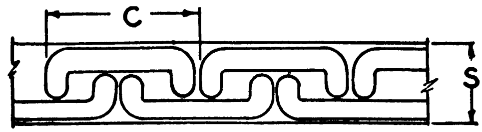


FIG. 2.—A more economical layout for the part shown in Fig. 1. This is the scrap-strip design generally used for blanks of this type.

assembly only the edges of the pieces were visible. Of course someone will say, "Such investigations should have been made in the first place." This argument again emphasizes the value of engineering collaboration.

Figure 3 is a new scrap layout made for the same piece with all the arcs omitted. Here an additional and different piece part, shown at *A*, can be incorporated in the same die. For clarity, the die openings in the line cuts are section-lined. The two U-shaped pieces of work are cut apart on line *X-X*, while one is being cut off on line *Y-Y*, using a suitable punch in the last station. It will be observed that no scrap frame remains after the blanks are cut, because width *S* equals the length of the piece. This layout utilizes nearly 95 per cent of the strip.

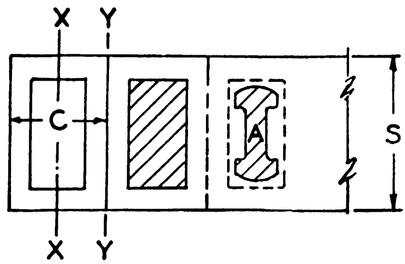


FIG. 3.—The most economical layout for the part shown in Fig. 1. It includes blanking an additional piece at *A*.

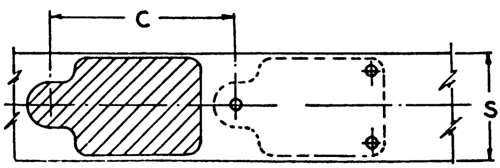


FIG. 4.—A scrap-strip design for piercing and blanking the piece shown by using only 65 per cent of the strip area.

Saving Metal by Interlocking Blanks.—Figure 4 represents a piercing and blanking layout where a scrap strip is passed out from the die. This is another wasteful layout, since only 65 per cent of the strip area required for one blank is used. However, by omitting four unnecessary round corners, and by cutting the forward end of the blanks out of the rear end of the blank ahead, and reducing *S* to the width of the work, a layout is obtained that uses practically 100 per

cent of the strip, as shown in Fig. 5. Press tools for this type of blanking are sometimes called "no-scrap dies."

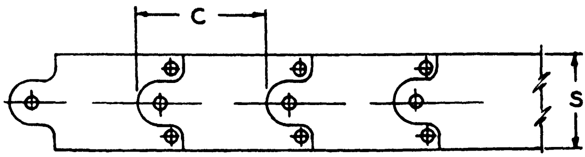


FIG. 5.—A layout for the blank shown in Fig. 4 that uses practically 100 per cent of the strip area.

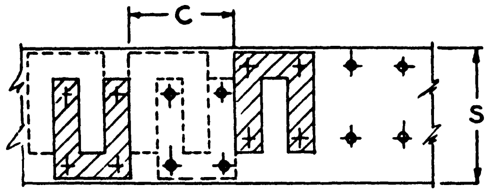


FIG. 6.—A highly economical scrap-strip design for U-shaped blanks.

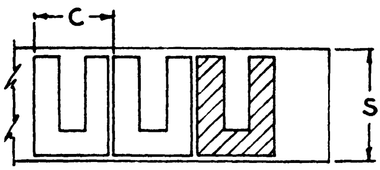


FIG. 7.—A layout for U-shaped blanks that utilizes only 54 per cent of the strip.

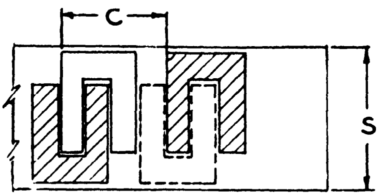


FIG. 8.—A layout for U-shaped blanks that utilizes 75 per cent of the strip.

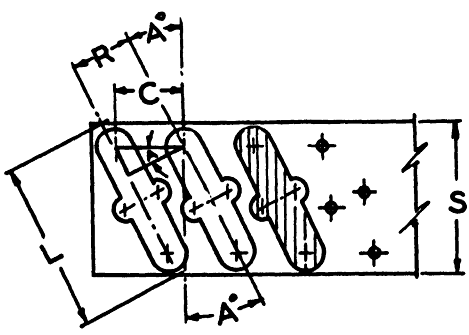


FIG. 9.—This layout is obviously not an economical one for the blank shown.

Miscellaneous Layouts and Formulas for Scrap Strips.—Figures 6 to 8, inclusive, show the developments of scrap-strip layouts for typical U-shaped blanks. Figures 9 to 11, inclusive, show the saving in metal gained by changing from single to double rows of blanks. Figure 9

is lettered to suit several mathematical formulas used in checking the correct positions of blanks that lie at an angle across the strip.

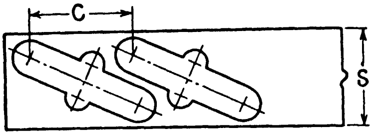


FIG. 10.—The blank in Fig. 9 repositioned to give a 23 per cent increase in the saving of metal.

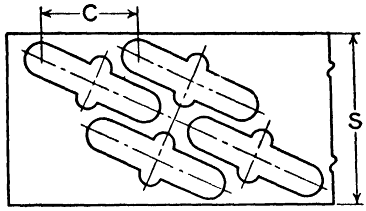


FIG. 11.—The blank in Fig. 9 positioned in a double row to increase metal economy 38 per cent.

By construction, angles A are equal.

$$\cos A = \frac{R}{C} \quad \text{or} \quad \frac{S}{L}$$

Hence,

$$\frac{R}{C} = \frac{S}{L}, \quad \text{and} \quad (C \times S) = (R \times L)$$

$$C = \frac{R \times L}{S}$$

$$R = \frac{C \times S}{L}$$

$$L = \frac{C \times S}{R}$$

Pounds of Stock Required per 1,000 Blanks.—When P is the weight of the material per square foot, and W is the pounds of stock necessary to make 1,000 blanks, then $W = C \times S \times P \times 7.3$. This formula includes 5 per cent allowance for waste ends and miscuts. When C and S are intended for blanking multiple rows, the final result obtained by the formula must be divided by the multiple to obtain the weight per 1,000 blanks.

Choosing the Right Scrap Strip.—In laying out economical scrap strips, it is often difficult to determine which arrangement is most desirable. An illustration of such a difficulty is shown in Figs. 12 and 13. In this case, the blank has a curved contour with rounded ends, a shape often encountered in die work. The piece was laid out first for a double row of blanks, as seen in Fig. 12. This scrap strip proved to be too wasteful, so another arrangement was tried, that shown in Fig. 13. However, the layout in Fig. 12 was found to be only 13 per cent more wasteful than the one in Fig. 13. After considering the

formed angles in this blank, Fig. 14, and that its four corner bends were parallel with the grain of strip in Fig. 13, it was necessary to choose the design in Fig. 12, although it was slightly more wasteful. When sharp

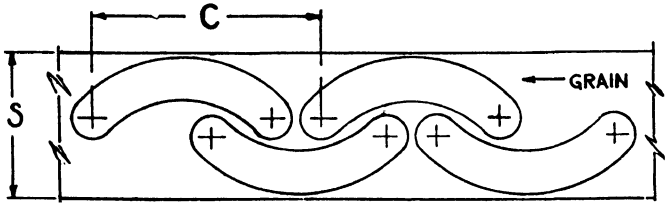


FIG. 12.—Arc-shaped blanks cut from a double row and using long blanking centers.

corner bends are not positioned across the grain, they may fracture in the bending operations that follow if the material is heavy gage.

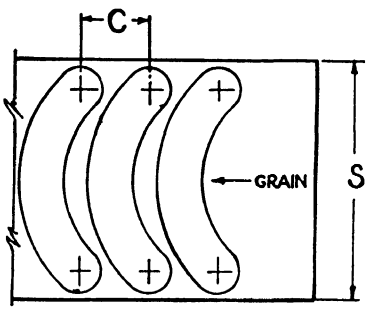


FIG. 13.—Arc-shaped blanks cut from a single row and using short blanking centers.

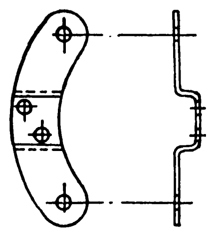


FIG. 14.—Arc-shaped blank after being formed.

Avoid Double Rows.—Running double rows of blanks in one strip should be avoided if possible, especially when it makes the strip too wide for easy handling. Another fault in double rows is that, unless great care is used in starting the second successive row of cuts, the blanked openings will "creep" ahead until the cuts project over into the first row. This condition makes imperfect blanks and more waste. Furthermore, partial cuts may deflect the punches, and nicked cutting edges will result. This trouble may lose more time and expense in die repairs than is gained by attempting to run a double row. However, when the blanks are large, of heavy expensive material, and of high output, the double-row system must be followed. When there is only a little difference in the economy between several strips, select the one having the least width, or of the least blanking center distances. Shorter blanking centers increase the speed of running the job.

L-shaped Blanks.—Figure 15 shows a layout for blanking the well-known L shape. This blank is subsequently formed along line *F*; it must therefore lie at an angle of at least 30 deg. across the strip grain to prevent fractured corner bends. This layout is made for a double punch and die. Two blanks are made at each press stroke, as indicated

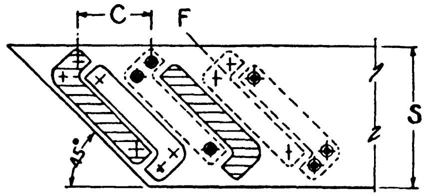


FIG. 15.—Scrap-strip design for cutting L-shaped blanks, two per press stroke.

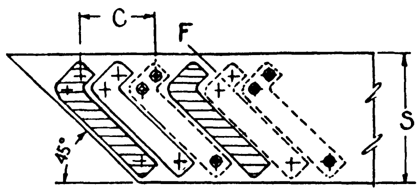


FIG. 16.—Another and a better scrap-strip design for the L-shaped blank shown in Fig. 15.

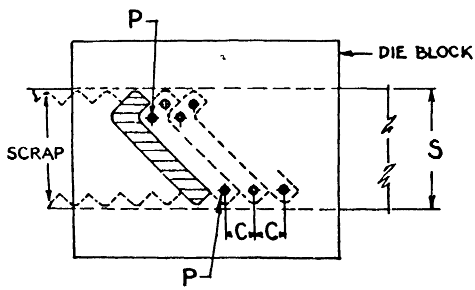


FIG. 17.—A high-economy scrap-strip layout for cutting L-shaped blanks.

by the two die openings which are section-lined. The blanks lie in opposite directions. This layout is wasteful of material since it uses only 63 per cent of the strip.

The layout in Fig. 16, for the same piece, appears much more economical, but it increases the saving only about 10 per cent, compared with the layout in Fig. 15. It uses 73 per cent of the strip and makes two blanks per press stroke. The layout in Fig. 17 for the same piece uses 91 per cent of the strip; however, this die produces only one blank per press stroke. The work is aligned by pilots that engage in

holes *P-P*, but unless this die can be run at nearly double the speed of the one in Fig. 16, the latter layout must be adopted because it produces two blanks per press stroke. The layout in Fig. 17 also has the faul of trying to align previously made cuts with those made subsequently, causing slight notches in the edges of the blanks. Unless such deviations as these are permissible, this die strip could not be used.

Computations Determine the Waste or Saving.—If the manufacturers of automobile bodies did not utilize the sheets of metal cut out for door and window openings, they could not successfully compete with the manufacturers who did. Of course, this kind of saving is self-evident, but for blanking-strip layouts, the saving is not always so clear. A casual inspection of a scrap layout is a poor way to determine its waste or economy. Layouts must be carefully figured to discover waste, or to determine how much material and cash will be saved.

A recent case where many small blanks were being cut from expensive material illustrates the point. This job had been running for several months when someone discovered that the die could be altered and a substantial saving made. At first, the saving seemed rather disappointing—it amounted to only ¼ lb. per 1,000 blanks—but a further computation showed a total saving of nearly $4,000 annually! It was the high yearly output that demonstrated the real value of the change in strip layout. This shows the importance of the subject in terms of cash when the material is costly and the output high.

Difficulties Encountered in Scrap-strip Designs.—A drawing of the scrap strip suggests practically the entire design for the die. It shows the size and type of die required and the general dimensions of the tool. First of all, the scrap strip must be of the right design. Then about all that is necessary is to put the idea down on paper, get the drawing and material into the shop, and start construction of the tool.

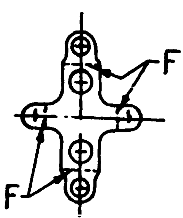


Fig. 18.—A type of blank for which several different scrap-strip designs can be made.

The layout for the blank shown in Fig. 18 is rather difficult. This blank is to be formed in a second operation. The dotted lines *F* are the bending lines. These lines are positioned at right angles to each other, which means that the blanks must be positioned in a bias direction across the grain in the strip. The purpose of this is to prevent fractured corners in the bends.

There were several attempts made before a successful layout was found. Figure 19 shows one of them; space does not permit showing all the others. The shape of this blank can be made to enter into a large

variety of different scrap designs. The double row of blanks shown in Fig. 20 was decided upon as the best and most economical, but there are other designs substantially as good as this one. Layout *B* is an example of a single row, but it is not so economical (by 20 sq. in. of material per 1,000 blanks) as the double row. This blank is not large enough to make a double-row strip too cumbersome in handling.

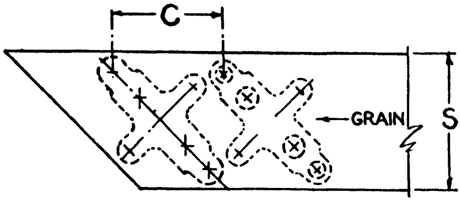


FIG. 19.—This single-row scrap-strip design for the blank shown in Fig. 18 is very wasteful of material.

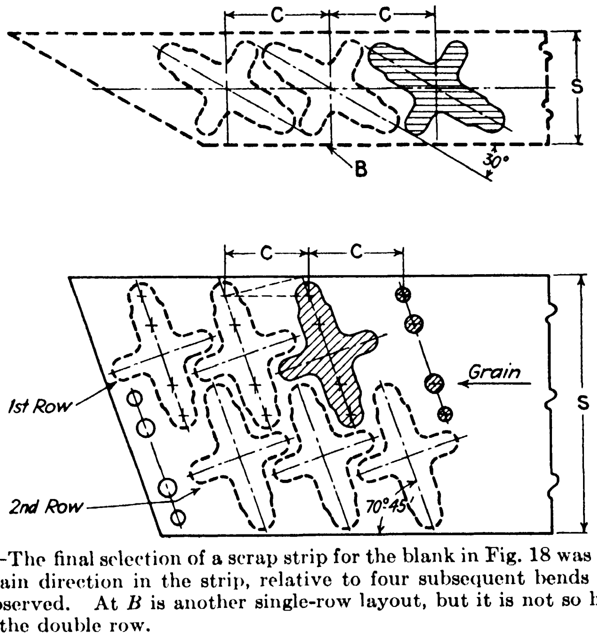


FIG. 20.—The final selection of a scrap strip for the blank in Fig. 18 was a double row of cuts. Grain direction in the strip, relative to four subsequent bends in the work, should be observed. At *B* is another single-row layout, but it is not so high in metal economy as the double row.

The double-row layout uses about 60 per cent of the strip area, which is ordinarily not a very high percentage but, in this case, was the best that could be done. After the first row of blanks is cut, the strip is turned "end for end" for the second row. There is a possibility here that a third and fourth row could be run, but it was found that wider strip would be too cumbersome for easy handling and that changing the gages on the die was undesirable.

Another type of blank similar to this one is that for the developed shapes of certain bumper guards for automobiles. The material for these guards is heavy strips of steel, $\frac{3}{32}$ to $\frac{1}{8}$ in. gage, and for a double row the strip may be too heavy to handle rapidly. This type of blanking is done in a straight-side press. The strip is entered at the front of the press and passes out at the rear. Two operators are sometimes needed for handling such operations, one at the front of the press and one in the rear. The strips are usually 8 to 10 ft. long. A single row of such blanks often is far too wasteful, and a double row is the only way in which to economize material.

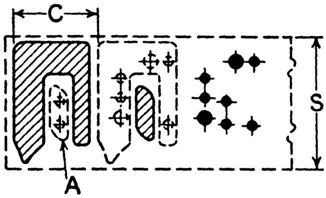


Fig. 21.—A scrap strip in which two different blanks are pierced and blanked simultaneously.

Cutting Blanks from Scrap.—Figure 21 includes a secondary blank at *A*. It is not often that a blank of an entirely different shape can be cut from the scrap of another blank simultaneously. This condition is much sought for; it is not only a direct saving of material, but it saves the cost of building another die and an additional operation. This layout uses about 75 per cent of the strip area. Layouts that utilize three-quarters of the strip area, or more, are considered of good economy.

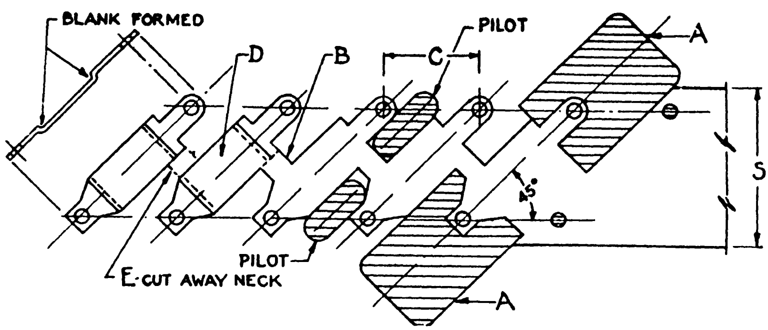


Fig. 22.—A simple scrap-strip layout for a five-station progressive die.

Progressive "Cut-and-carry" Dies.—These types of press tools do not push the blank through the die. The blanks ride along on the top surfaces of the die blocks. Only the pierced slugs and the notching waste fall out beneath the press. The blank contour is notched to shape by side punches, as indicated in Fig. 22, by the die openings *A*-*A*. A small neck, or connection of metal *B*, is left between the blanks for passing them along into stations ahead for additional operations. In

CHAPTER II

TYPES OF BLANKING DIES

PLAIN, COMPOUND, AND "TANDEM"

Blanking and "Stripping the Punch" with a Channel Plate.—The simplest cutting press tool is a plain blanking die with a positive channel stripper plate attached over the die block. A typical die of this type is illustrated in Fig. 27. This die produces the blank shown in Figs. 12 and 13. Only those dimensions indicated are required for this tool. Today, when tool drawings must be produced quickly, it is important to show only the necessary lines and to omit every part that is already understood.

Saving Drafting Time.—Figure 27 shows some drafting short cuts. Since the die set is delivered already built, there is no need to show more than a small part of it. Show the width, length, and thicknesses of the die shoe and punch holder. The parts to be omitted are indicated by the "light dashed lines" in the figure. Screws and dowel pins can be omitted, with the following reservation. The parts to be secured by them must be of sufficient size to include the screws and dowels. Sometimes, however, it may be necessary to show their sizes and locations.

Show coiled springs as a dotted rectangle with crossed diagonal lines. Indicate threads by using two parallel lines, as in all the tool sketches given in this chapter.

Which Parts to Show.—In order to make the stock list for ordering the die materials, all parts, other than the die set, should be drawn to scale and dimensioned. The parts can be assigned detail numbers to facilitate ordering.

Automatic Stop.—The automatic finger stop illustrated here works properly only when its retaining slot *A* provides a loose fit to permit a slight horizontal "swing" of the finger. This movement should be as much as, or more than, the thickness of the work strip. The object of the "swing" is to allow the tension spring to pull the stop over the "scrap bridge" when the ram *descends*, so that when the ram *ascends* the finger tip will come down on top of the bridge, and not in the blanked opening from which it was just lifted. This action permits

hort lengths. This system is best adapted to blanks of irregular es where there is a considerable saving of material by "nesting" lanks, as seen in Fig. 26.

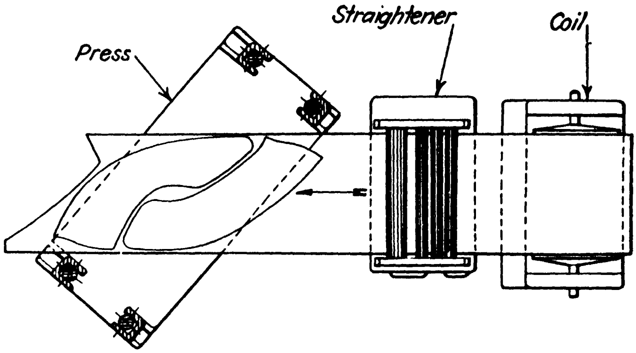


FIG. 26.—Plan of a feeding and straightening machine where wide sheet material is fed at an angle of 45 deg. into a blanking press. This positions the strip relative to 'he die opening to favor economy of material. Two army-truck fenders can be blanked .n pairs, 26 blanks per minute, with minimum waste. This suggests the necessary expedient used at times when a scrap strip is too wasteful. By changing the feeding angle of the strip over the die, a more economical scrap strip can sometimes be obtained, but this cannot be done unless the die has only one station.

Coiled strip steel is now available up to 80 in. wide, some of the heaviest coils weighing up to 20,000 lb. The saving of steel in avoiding waste ends for some of the "nested" blanks amounts to a large sum daily. This illustrates the advantages in cutting large blanks from long coils of sheet stock.

Thin strips 8 to 10 ft. long, spot-welded together and aligned in a special welding fixture, may be used. But the lapped weld slows down press operations, and the cost of the extra operation may wipe out the saving made.

Some manufacturers have fastened ends of strips together with surgeon's tape, but this has the same difficulties as spot welding. It is slower than welding, and to align the strips properly and roll them into coils on a motor-driven reel has proved too expensive.

After all, it may be found that the best way to save waste ends is to let them accumulate beside the press and then make a special job of running them through the die.

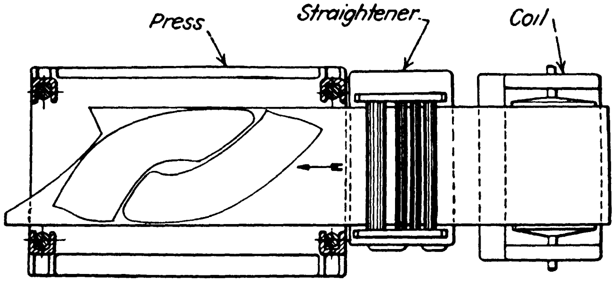


Fig. 25.—Plan view of a feeding and straightening machine in which wide sheet material is fed between the uprights of a double-crank press or into a four-point blanking press.

Straight-side Press Feed.—The method of feeding wide material is through the right-hand uprights of the press, as seen by the floor plan in Fig. 25. This requires a press with a large opening between the uprights, from 50 to 75 in. wide, depending on the width of sheet.

Ease and speed in handling the coil, however, are obtained with a hydraulic drive feed, because with it the sheet can be "inched" into its first position under power. A feed selector switch is turned to "automatic," and the press is then run "on the jump." The feed starts as soon as the die opens and automatically runs through its cycle of high speed, low speed, and stop, feeding 95 in. or any length for which it is set.

Measuring Device.—The feeding length is controlled by an automatic measuring device which can be adjusted to feed any length from 25 to 125 in. But provisions for 160- or 200-in. feed lengths are also made. A graduated hand wheel is mounted on the measuring device for making the necessary adjustments. This figure and the one following were furnished by courtesy of F. J. Littell Machine Co.

Hydraulic Drive Feed with Press Diagonal.—Here are further details about blanking from coiled sheet stock rather than from sheets

the case illustrated, the blank is formed at station D, just before its connecting neck is severed at E.

Some cut-and-carry layouts involve expensive material and 8 or 10 progressive stations; these require very careful calculation of their scrap strips, from the standpoint of material economy. The layout shown in the figure is a simple one, but it is typical of the cut-and-carry principle. Two elongated pilots enter the slots between the blanks and align the strip in both its forward and sidewise positions. In cut-and-carry dies, the economy of strip begins with its width. The width of strip is usually the same as the "bias length" of the blanks.

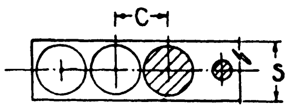


FIG. 23.—This is a wasteful scrap-strip design for cutting round blanks.

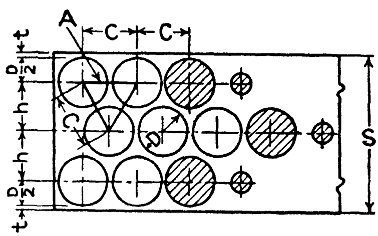


FIG. 24.—Illustrating the formulas for laying out and computing scrap-strip layouts for cutting round blanks.

There is no scrap frame to be passed out beyond the die. The operation illustrated consumes 60 per cent of the strip.

Circular Blanks.—A single row of circular blanks is wasteful of material, particularly when the blank diameters are large. In Fig. 23, the average utilization of material is about 62 per cent. In a double row, the average utilization rises to 72 per cent, but for a triple row it increases only to about 77 per cent.

When more than three rows are used, the percentages of gain decrease rapidly. With a wider and more cumbersome strip to handle in the press the die operations are slowed down—unless the blanks are very small—until the saving is lost. For large round blanks, the percentages of saving are somewhat larger than those given above. In Fig. 24, A is an equilateral triangle, and h is $C \times \cos 30$ deg., or $0.86603 \times C$. Strip width S is then $2h + D + 2t$, in which D is the blank diameter and t the thickness of material.

Saving Strip Ends.—The ends of short strips that cannot be fed entirely through a blanking die are a problem in the pressroom because they represent waste. The use of coiled stock relieves this trouble considerably, but coils of strip are now difficult to obtain because of priority ratings

pushing the strip steadily against the stop, while the tip on the finger is being raised and lowered automatically, by the movement of the ram, into and out of the successively blanked openings in the strip. An adjustable vertical rod, not shown, is attached at the front of the punch holder and directly over the outer end of the finger, for operating the stop automatically.

Stripping the Punch.—The punch is cut through the sheet in its downstroke, but is "stripped" from the punch in its upstroke. This action occurs when the punch carries up the sheet into contact with the roof under the channel plate.

Other Details.—The view of the punch-holder face is obtained by imaginarily lifting the punch holder straight up and off the guideposts, and then turning it clockwise, face up, at 180 deg.

Dimension *B* allows clearance between the die and guidepost for the nut on the surface grinder wheel. If *B* is less than about 5/8 in., the nut may interfere with the post when grinding the die.

Dimension *E* is an oil pocket, above the guide bushings, for retaining lubricant for the posts and bushings.

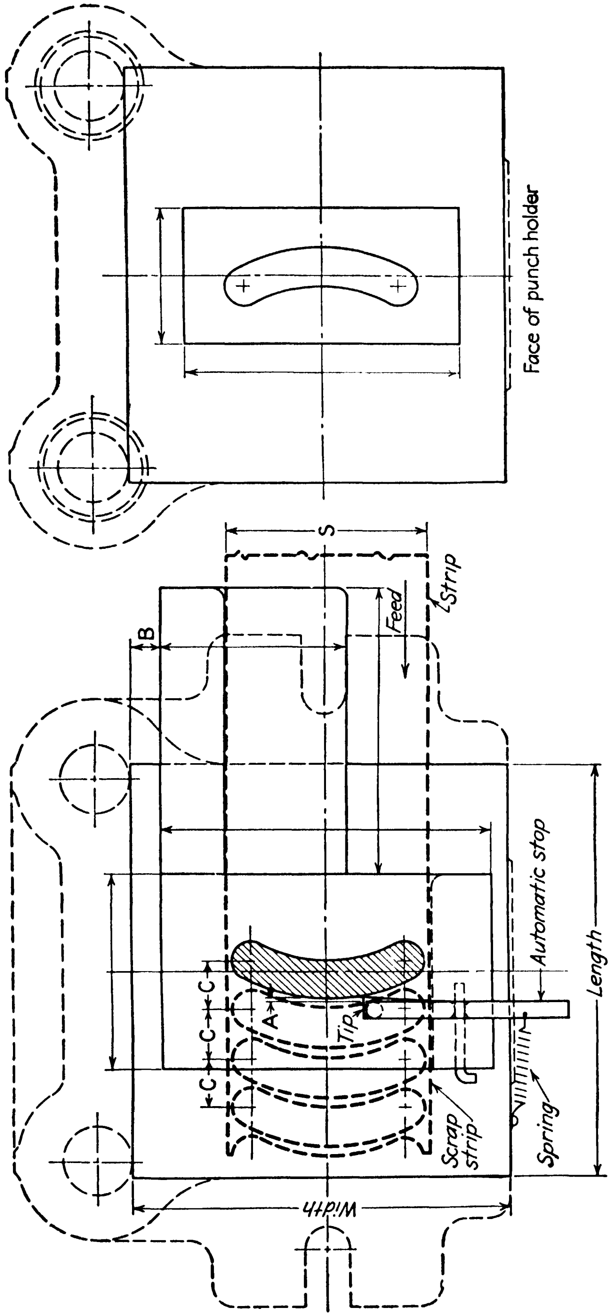
The guide bushing shoulder *G* should be long enough to prevent it from uncovering the ends of the guideposts when the ram ascends to its maximum height.

This tool is called a "drop-through die." As the name implies, the cut blank drops through the die and shoe, next the bolster plate on the press, and finally through the opening in the bed of the press.

Filler Plates.—In large dies the punch and die members are "backed up" with cheap filler plates, or spacer blocks. Usually cold-rolled steel is used, but to save war materials Masonite or even hardwoods have been used recently. Other details shown in connection with the die in Fig. 27 are applicable to all blanking dies, such as: dimensions *B*, *E*, *G*, and *L* and the use of filler plates.

Blanking and "Stripping the Punch" with a Spring-pad Plate.—This die has no automatic stop, because there is no place to attach one. It is a hand-fed die and uses a pin stop, as seen in Fig. 28. This is the easiest method known for positively stopping a strip when cutting consecutive blanks. Notice that the stop pin is located well below the center of the blank. This feature permits clearing the pin easily when raising up the front edge of strip for feeding it forward. Stripping off the scrap is done by a spring-pad plate surrounding the punch.

Spring-pad Stripper Plates.—This die is shown cutting the second row of blanks illustrated in Fig. 11. Here we see the necessity for substituting a spring-pad stripper plate in place of a positive channel plate. In cutting the first row in a double row of blanks, the strip


Face of punch holder
S
Strip
Feed
B
Automatic stop
Length
C
C
C
A
Tip
Scrap strip
Spring
Width

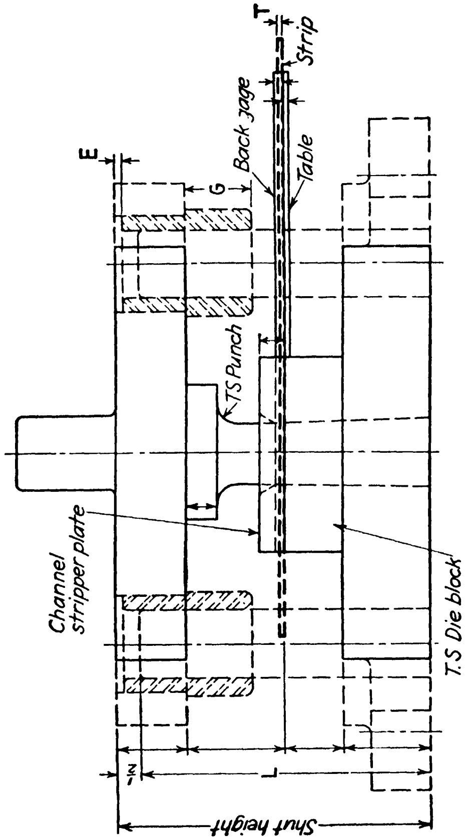


FIG. 27.—Plain blanking punch and die in which the punch is "stripped" by a positive channel-stripper plate. This type of die can be fed rapidly by hand because it has an automatic stop finger.

usually becomes "bowed." Obviously, it would be impractical to attempt feeding a bowed strip through a straight channel plate.

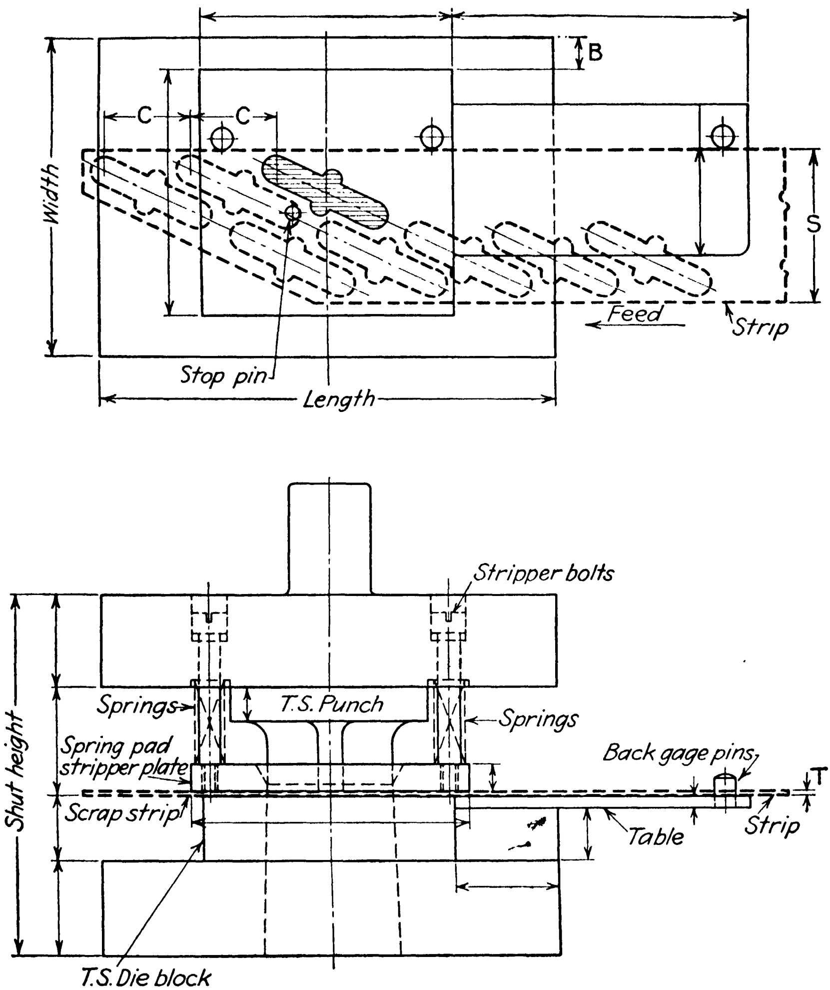


FIG. 28.—Plain blanking punch and die for cutting a single row of blanks or by running a wider strip twice through the die, a double row. "Stripping" is done by a spring pad that surrounds the punch. This die uses a hand feed and pin stop. It is a drop-through die.

Furthermore, when cutting large blanks from light-gage materials, a spring-pad pressure plate becomes necessary, because it contacts the sheet ahead of the punch. All irregularities are thus flattened before the blank is cut.

In this type of die, the work is in full view of the operator, except during the brief interval of blanking.

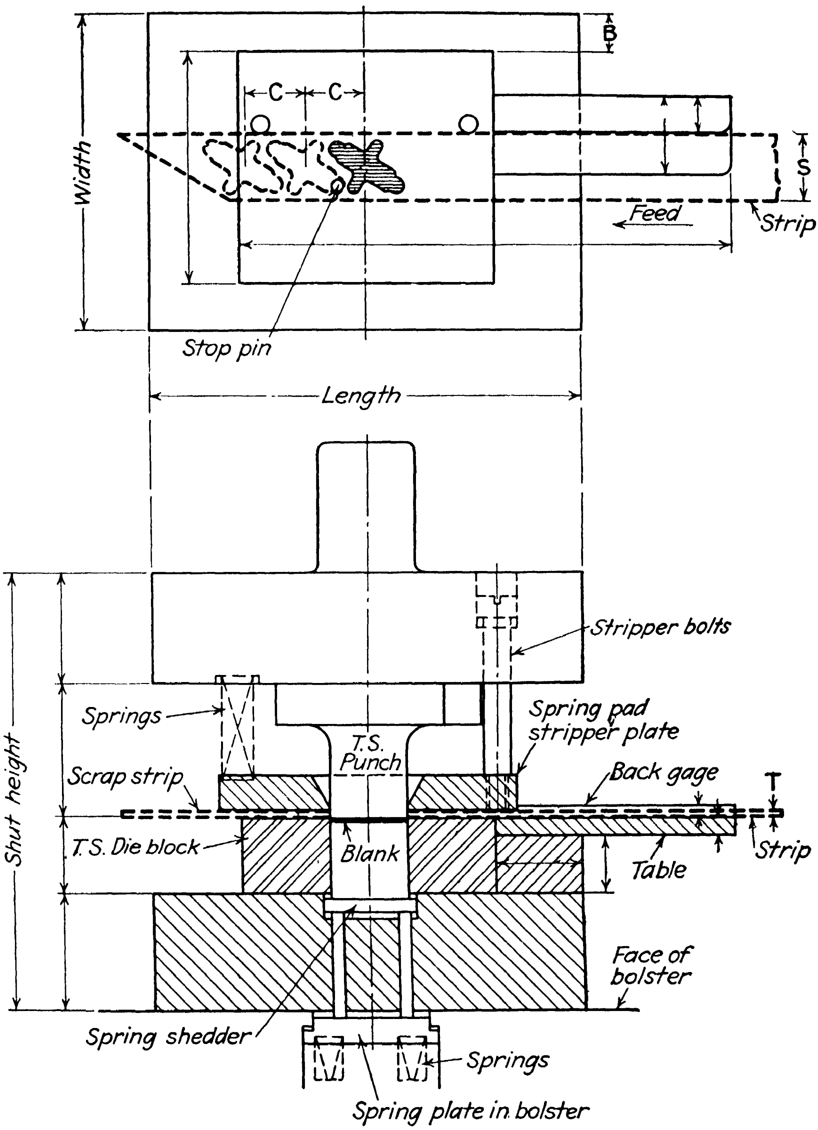


FIG. 29.—Blanking punch and die that cuts a single row of blanks. When the punch ascends, the spring pad follows up with the blank and inserts the blank flush within the opening of the strip whence it came.

When the ram ascends, the spring pad "strips" the scrap frame from the punch, while the sheet is still flat on the die.

Using a spring-pad stripper plate for small work permits the blank to be returned again into the strip, if necessary, and then carried forward for subsequent operations.

Cutting and Returning Blanks into the Strip.—Figure 29 represents a blanking die which is not a "drop-through die." This is a semi-compound die, in which the blank is delivered above the die block.

In operation, when the ram descends, a spring-pad stripper plate contacts the sheet first and holds it flat down on the die; the punch then continues to descend and cuts a blank into the die. The die block is fitted with a sliding spring shedder, and the cut blank lies between the faces of the punch and shedder. When the ram ascends, the shedder and blank follow up the punch, and the spring-pad stripper plate holds down the sheet while the shedder, continuing to rise, inserts the blank up into the cut opening whence it came.

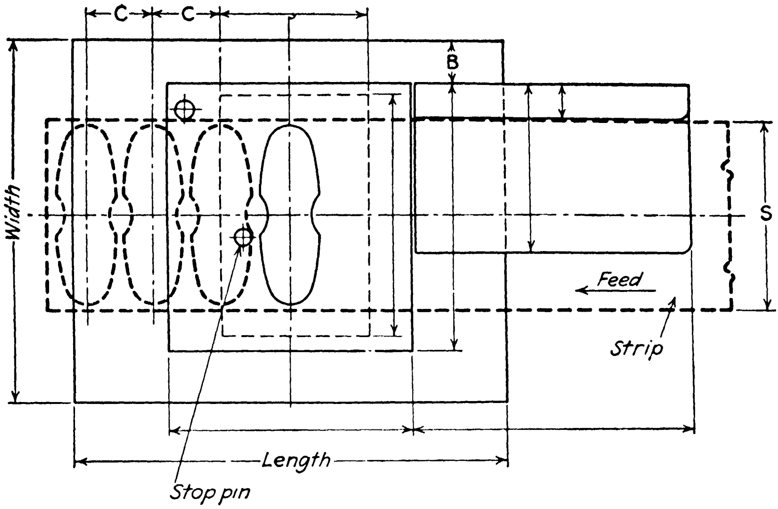
Uses for Returned Blanks.—For large work, this tool delivers the blank above the die, which is convenient where the press bed is too small to permit large blanks to drop through. For small work, the inserted blank may be passed along in the strip for subsequent operations, as illustrated in and described under Figs. 57 and 58.

However, in order to make this kind of operation successful, the material thickness must have a definite relationship to the length, shape, and area of the blank. With small blanks like the one shown—taken from Fig. 20B—the material should not be less than about 0.040 in. gage.

Large blanks, cut in a straight-side press, are knocked out of the strip by another operator in the rear of the machine. Small blanks can be ejected through a clearance hole by the descent of a punch finger. If the blanks are long and narrow, and positioned approximately across the strip, they can be recovered by passing the strip over a roller of suitable diameter.

Compound Inverted Dies.—Figure 30 is a layout for an inverted compound die, arranged with a vertical rod attached to a "knockout" pad. The die block is attached on the punch-holder face, and the punch—surrounded by a spring pad—is attached on the face of the shoe and symmetrically positioned under the die.

Operation of the Die.—In the drawing, this tool is shown at its shut height. The blank has been cut into the die, and in the upstroke the spring pad ascends and "strips" the sheet from around the punch. The die and blank continue to ascend until the stop block contacts the knockout bar through the head of the press, and this action immediately depresses the rod and pad, thus ejecting the blank. If the



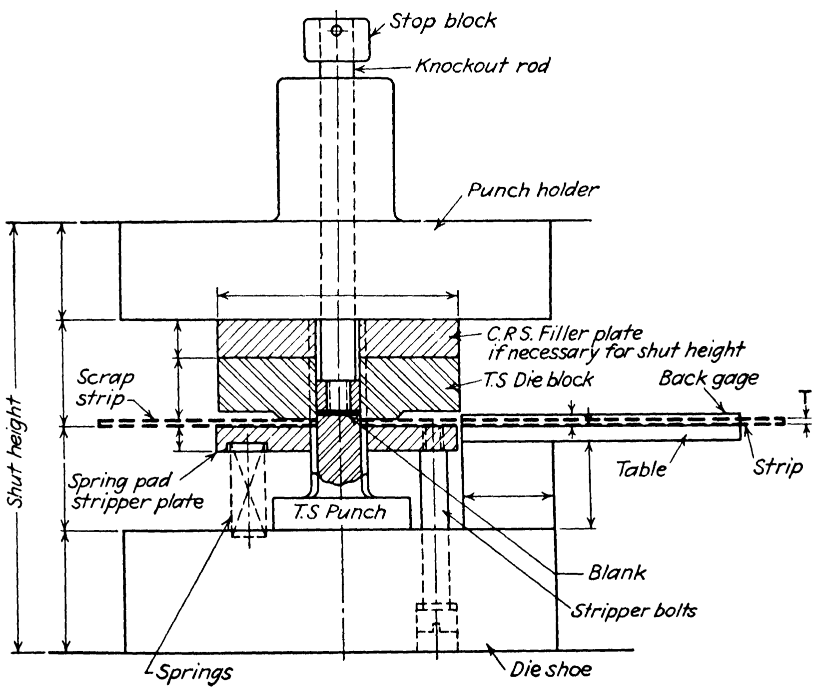
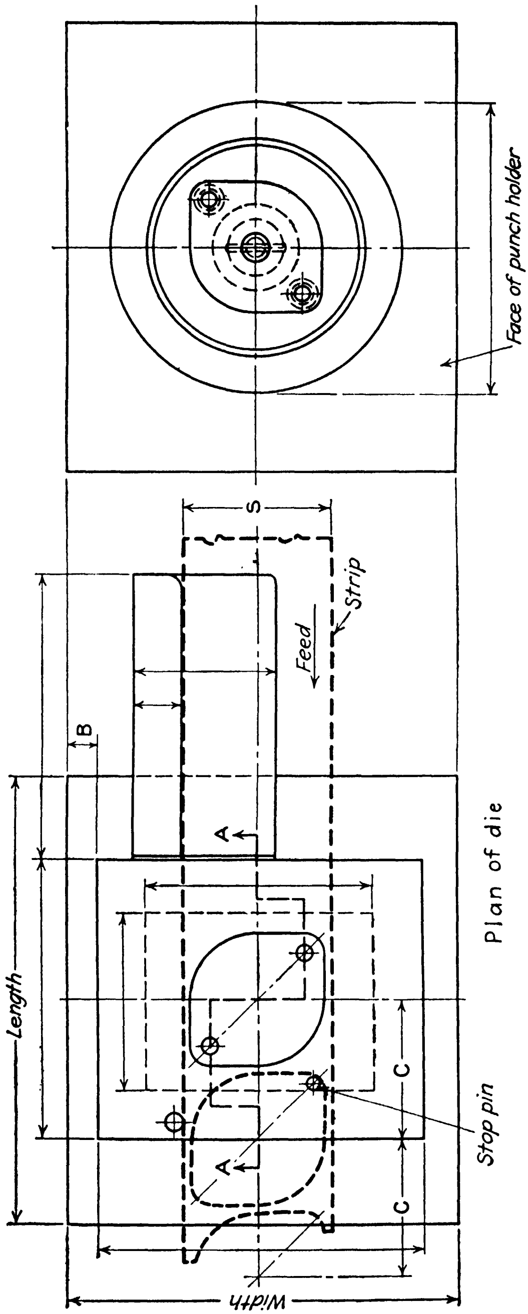


FIG. 30.—An inverted compound blanking punch and die. This tool cuts a blank, "strips" the sheet from the punch on the upstroke, then ejects the blank out of the die near the top of the stroke.


Face of punch holder
S
Strip
Feed
B
A
A
Plan of die
Length
C
C
Stop pin
Width

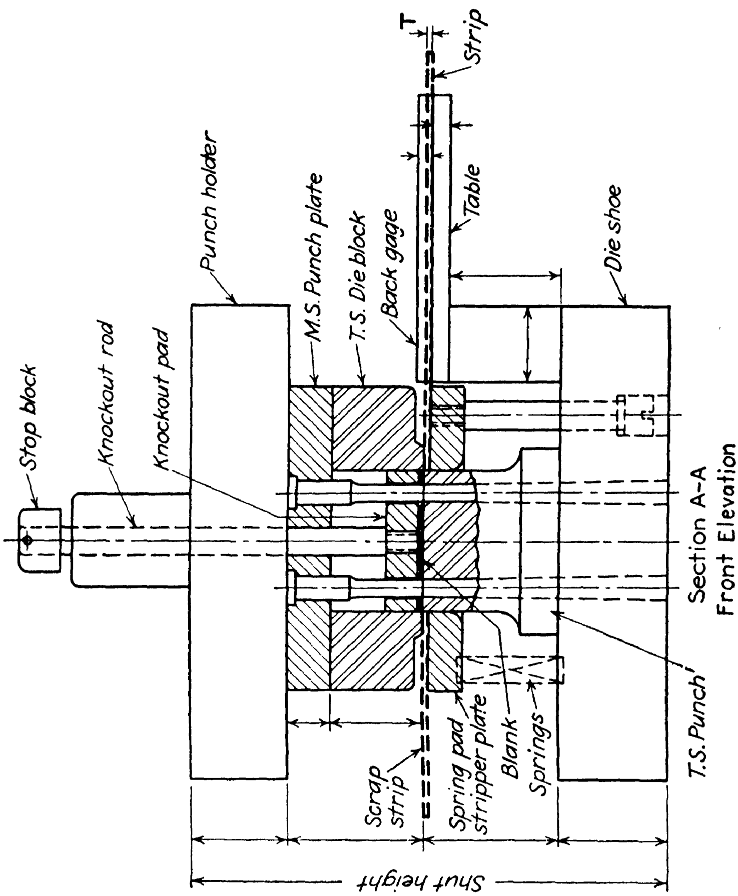
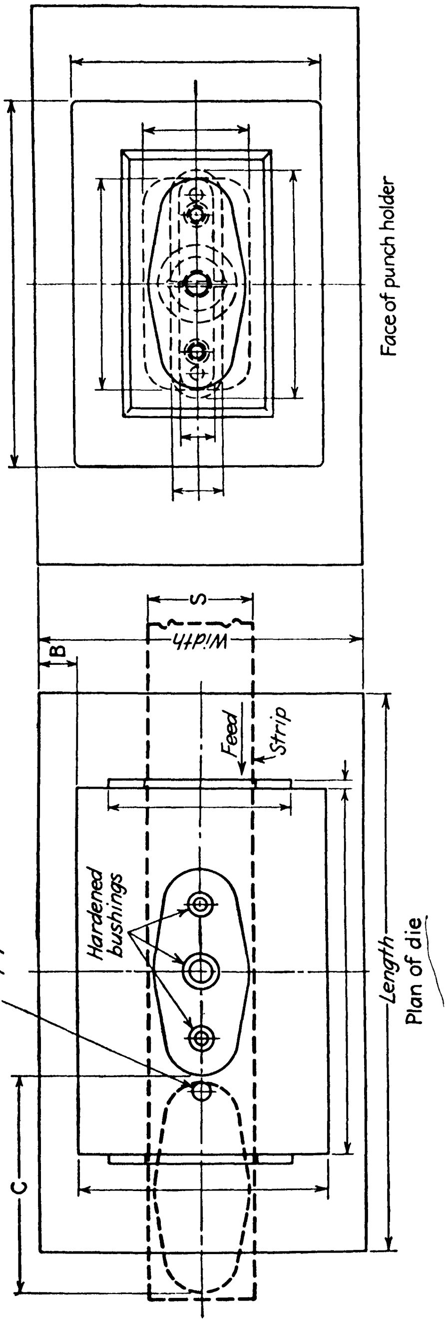


FIG. 31.—An inverted compound blanking and piercing die performs all its operations at one station. These dies are used because they can be made to produce high-precision work. But their accuracy is no greater than that of the diemaker.


Face of punch holder
S
Width
B
Feed
Strip
Hardened bushings
Stop pin
C
Length
Plan of die

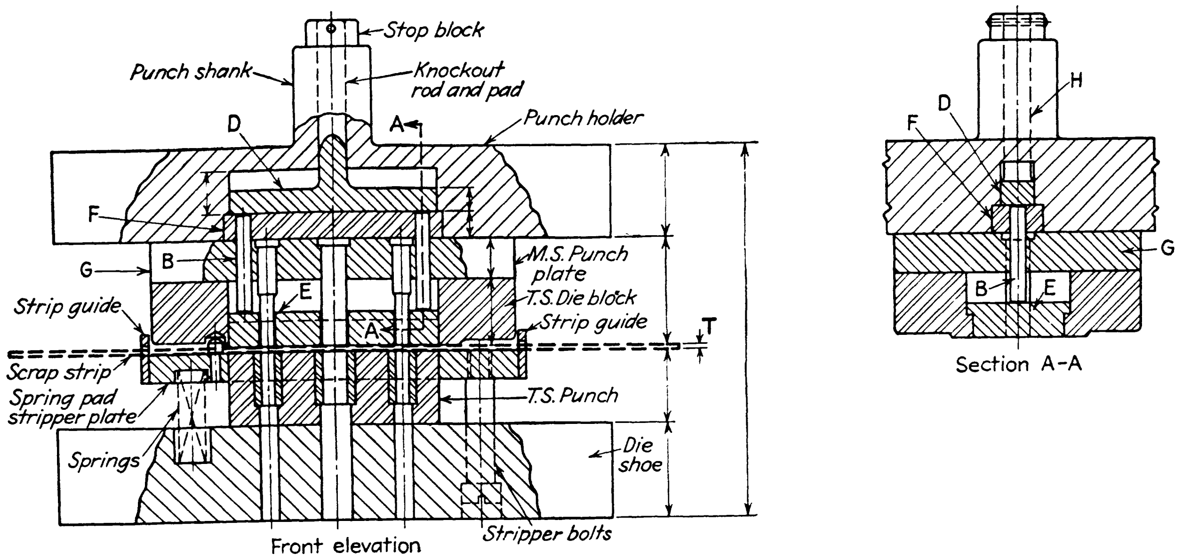


FIG. 32.—Inverted compound blanking and piercing die with a hardened bridge plate *F* for backing up the piercing punches. The plate fits a slot milled in the punch holder; the ejector pad *D* rides in a narrower slot above the bridge. This design provides space for operating a knockout mechanism for ejecting the blank.

press has been previously tilted back, the work drops on the strip and then slides off behind the machine.

Uses for the Stop Block.—The stop block is "pinned" on the upper end of the rod and is a precautionary measure. It prevents the rod from falling out, and if the press is inadvertently operated during the "tooling setup" and the knockout bar is adjusted too low, it prevents smashing the rod and its attached mechanism. In some dies, the attached mechanism is rather complicated, and not only is it expensive to replace, but, which is worse, the job is held up and the press is idle.

Advantages of the Inverted Die.—This die can be run in a press in which the bed opening is too small to drop through the blank. It can be used on a bolster plate which has no opening. In heavy blanking operations, this die eliminates much of the "tool spring" and some of the "spongy" conditions resulting from large openings under the die. These difficulties are quite noticeable when blanking heavy work in "drop-through dies."

How Much Spring Compression?—Coiled compression springs will last longer and avoid splits and fractures if not compressed more than two-thirds of the difference between their free lengths and solid heights. For low-production dies and moderate speeds, this limit can sometimes be safely exceeded, depending, of course, upon the length of the spring.

Compound Inverted Blanking and Piercing Dies.—The "high-spot" recommendation for these types of press tools is their great accuracy. When holes or other openings are perforated at the same time and at the same station in which the blank is cut, the interior openings are located, in reference to the blank outline, with the same invariable precision as was originally built in the tool.

This means that, if the toolmaker located any one of the interior punches 0.0005 in. erroneously, the error will repeat itself exactly as originally made, in each one of possibly millions of parts produced in his die. Figure 31 is the sketch of a simple compound inverted blanking and piercing die. This is a clear presentation of the design and operation of these press tools.

It will be observed that the round perforators are held in a punch plate mounted above the die block, and that the piercing is done through die holes bored in the face of the blanking punch. The pierced slugs fall out beneath the press. This tool needs no further description, because in design and operation it is identical with the tool discussed under Fig. 30, except that two holes were added in the body of the blank.

"Bridged Plate" for Backing Piercing Punches.—When one of the piercing punches, in an inverted compound blanking and piercing die, is at or near the vertical center line of the punch shank—through which the knockout rod must operate—then the knocking-out mechanism must be "designed around" the punch or punches to permit them to have a positively backed-up support. This can sometimes be done by locating the knockout rod "off center," but usually this design is insufficient. Figure 32 shows a case in point.

In section *A-A*, two ejector pins, *B*, lie vertically between the parallel pads *D* and *E*, and pass through holes in the hardened bridge plate *F*. Pad *E* is "shouldered" within the die block, so that it cannot fall out. Knockout rod *H* and its foot *D* are of one piece. Plate *F*, being wider and longer than *D*, is positively supported, against punch thrust, by an elongated annular shelf or shoulder that extends all around *D*.

Referring to the front elevation view, when a blank is cut into the die and the ram ascends, the stop block contacts the press knockout bar, which in turn depresses *D*, *B*, and *E*. This action ejects the blank from the die, but the three piercing punches are positively and permanently "backed up" by the hardened bridge plate *F*, which lies over them.

The screws and dowel pins through the die block, punch plate, and punch holder not only secure them rigidly on the punch-holder face, but also retain bridge plate *F* in place.

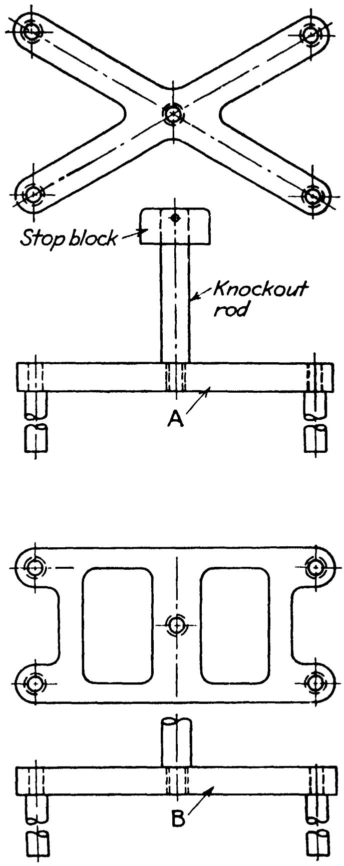


FIG. 33.—Rough steel knockout frames that work in slots milled in the punch-holder face can be of various designs to obtain backing-up areas between the slots for punches used in compound inverted dies. At *A* is the usual "spider" design, and at *B* the "slat" design."

Shapes of Knockout Frames.—At *A* in Fig. 33 is a knockout frame called a "spider," at *B* is one of "slatted" design. Both are used for the same purpose. These frames are of rough structural steel. They are burned out to shape with an acetylene torch, and then rough-ground freehand, around the edges, approximately to size.

Slots of sufficient clearance width and depth to permit free up-and-down action of the frame are milled in the punch-holder face. Knockout-rod diameters are made as large as possible to cause the frame to operate horizontally.

The object of making different designs of frames is to provide metal areas at the desired places to positively back up the piercing punches in compound inverted dies. Practically any desired shape of frame can be designed with openings that will expose metal faces in the plane of the punch-holder face for backing up various locations of piercing punches in order to meet all the exigencies of the case.

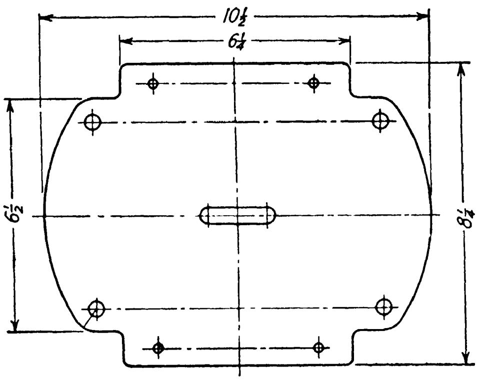


FIG. 34.—Steel blank produced in the single-station compound die illustrated in Fig. 35.

Springs and Knockout Frame Combined in Action.—Figures 34, the blank, and 35, the press tool, illustrate conditions often used to facilitate ejecting large work from piercing and blanking dies.

This tool is a sectional die. The punch and die members are each composed of 10 separately shaped pieces, which are rigidly "screwed and doweled" on the faces of the die shoe and punch holder, respectively. In plants where light manufacturing is done, this die is considered a large press tool.

In operation, the ram descends, a blank is cut into the die, and eight holes are pierced—all the cutting is at one station. The ejector pad within the surrounding die sections is depressed against several strong compression springs, and at the same time the stop ejector block is pushed up. In other words, we might say "the die is now loaded and cocked."

The ram ascends with the die and blank together, the compression springs having purposely been made too weak to eject the blank alone. When the ram nears its maximum ascent, the stop block is positively operated and completes the ejection in unison with the springs. In

other words, "positive contact on the stop block forced the cocked die to discharge its blank."

The advantages in using this type of ejection are several. (1) It relieves the "spider" knockout frame of bending action. (2) Spider arms can be made long enough to reach where action is needed. (3) The arms can be made of minimum thickness. (4) The action is positive and more efficient.

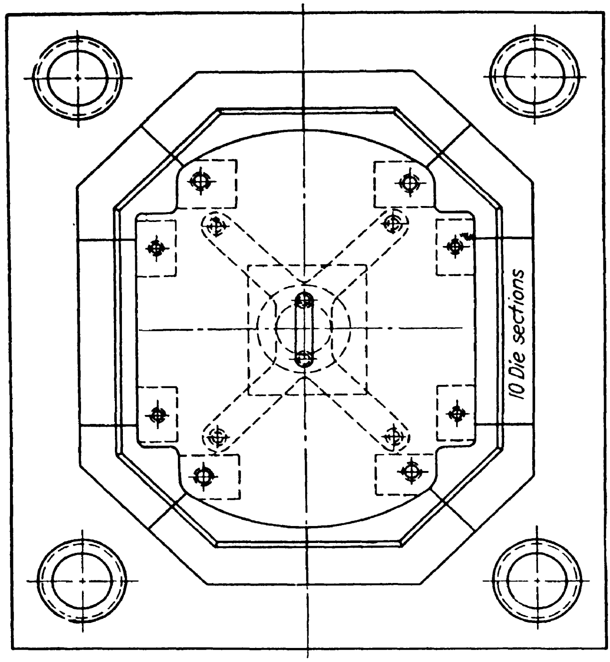
Disposing of Pierced Slugs.—Another feature in this die is the slug-ejecting slots cut across the bottom of the shoe. In very large dies some of the scattered holes are too far removed from the opening in the bed of the press to fall through. The slots are positioned directly under the clearance holes that lead from the piercing punches. The slugs fall into the slots and lie on the bolster plate; they are then pushed or blown out occasionally with a jet of compressed air.

Disposing of Large Blanks.—Blanks too large to pass through the press-bed opening can be easily recovered on the bolster plate. Figure 36 is the design for a plain sectional blanking punch and die in which the cut blank falls down through the die, filler plate, and shoe, and then rests on the bolster-plate surface. If a tilted press can be used, the blank slides off at the rear, but in a nontilting press it can be pushed out with a hand tool.

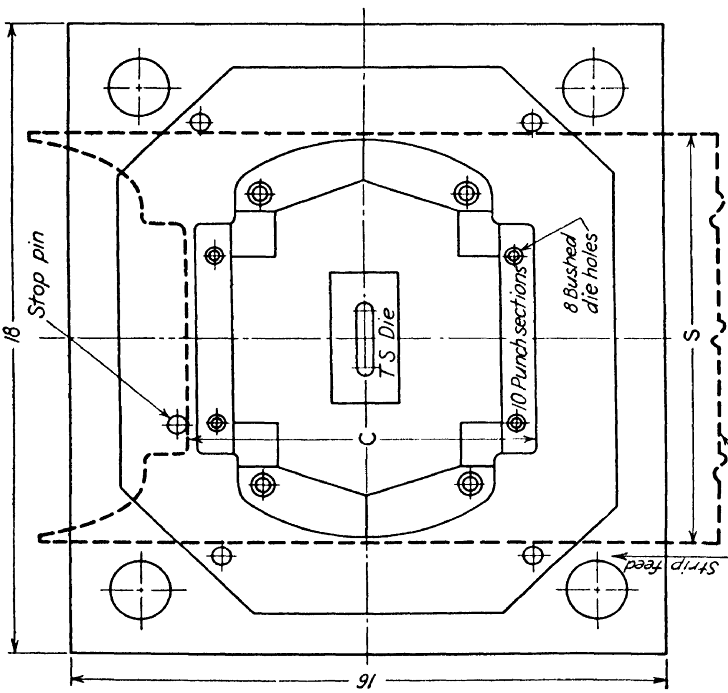
"Bumper Pins."—Bumper pins are a convenience in setting the tool in the press. They determine the shut height immediately and also check lost motion in worn ram slides. The position of these pins is shown in the tool sketch. In certain designs of forming, assembling, and riveting dies, bumper pins are used to ensure a constantly repeated position of the punch at its maximum downstroke. The pins should be large and have substantial shoulders. The punch and die sections are "backed" with cold-rolled steel filler plates. This is an economical measure; it saves using excessive quantities of expensive tool steels.

Steel-clad Die Sections.—Composite steel blocks can be used for punch and die sections. These blocks are of machinery steel with "welded-on" tool-steel faces. They are sometimes called "steel-clad blocks." The use of composite sections instead of solid tool-steel sections saves tool steel. Composite sections can be hardened before the holes for screws and dowel pins are drilled. This eliminates lapping the holes to ensure good fits in assembly, a procedure that must always be followed after solid tool-steel sections have been drilled and hardened. Composite sections can be bent to shapes, either hot or cold, without destroying the efficiency of the weld.

"Tandem" Piercing and Blanking Dies.—Figure 37 represents a steel blank to be produced rapidly in the tandem pierce and blank die



Face of punch holder



Plan of die

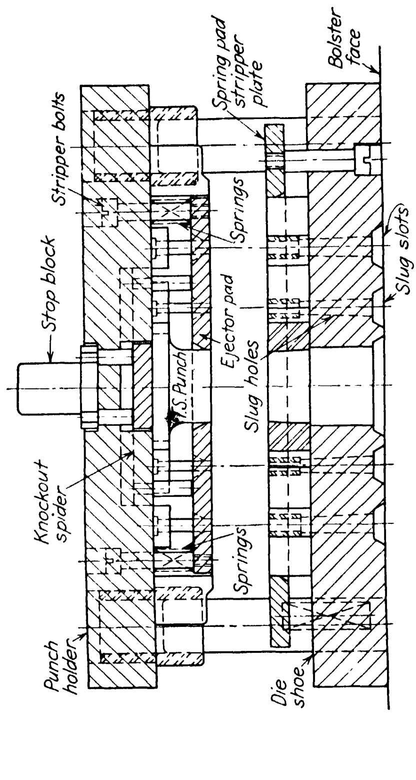


FIG. 35.—Inverted compound piercing and blanking die in which ejection of the work is accomplished by the combined action of compression springs and a knockout "spider" frame.

illustrated in Fig. 38. Tandem dies, sometimes called "follow dies," are two-step press tools. These dies are designed to cut one operation

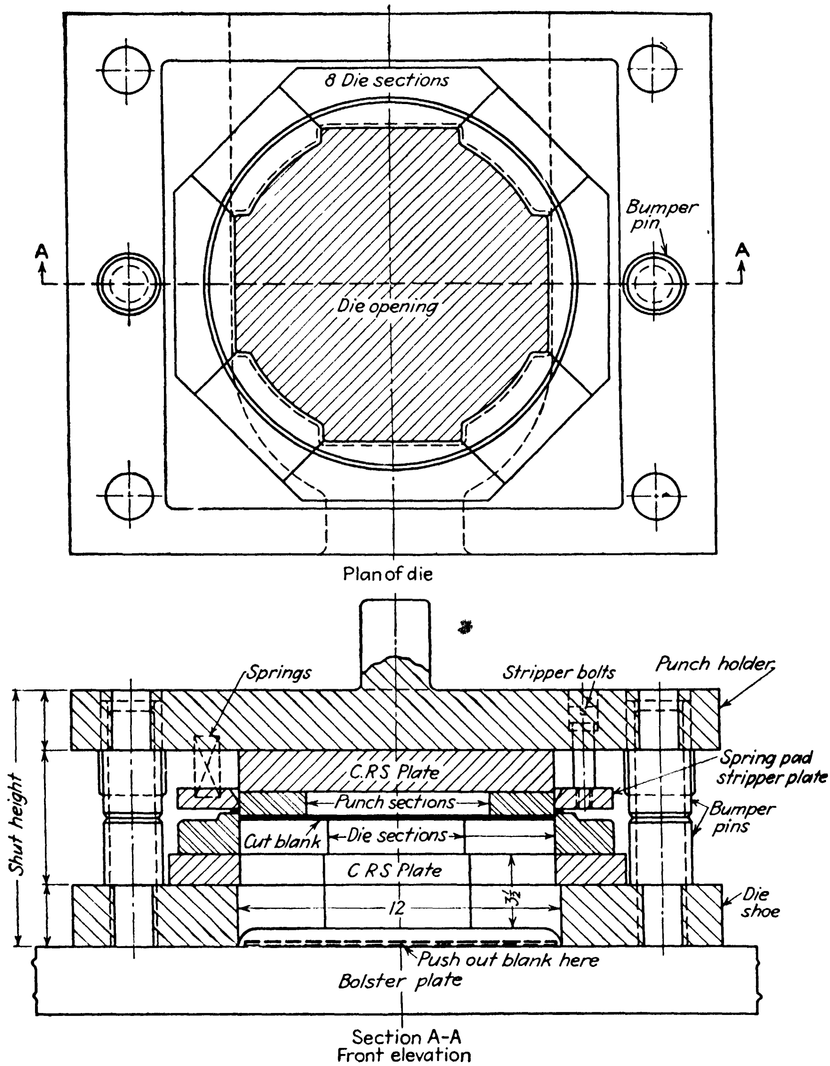


FIG. 36.—Plain blanking punch and die of built-up sections, illustrating a method for disposing of blanks that are too large to pass through the opening in the press bed. The blanks are cut through the die and fall on the surface of the bolster plate; the blanks are then pushed out through a clearance channel underneath the die shoe.

at the first station, with the strip checked against a finger stop, and then, after advancing the strip into the next station (distance C), to

cut the blank out of the strip while the punch registers the work with pilot pins that enter into one or more of the previously cut holes.

More Drafting Time Saved.—This sketch shows another time-saving method of drawing views. Instead of turning over the entire punch holder, face up at the right of the plan, to show the arrangement of the punches and flanges, these can be shown by light dashed lines on the plan view of the die. This can be done in most drawings of blanking dies; it saves the time of making an extra view. The method is shown in Figs. 38 and 40.

Progressive Piercing and Blanking Dies. When cut edges in blanks approach so near one another that the die openings would necessarily have weak spaces between them, as seen sketched in the blank, Fig. 39, it becomes necessary to lengthen tandem dies to include more than two stations. Some progressive dies may have six or eight stations. When dies have more than two stations they are no longer tandem; they are then known as "progressive dies."

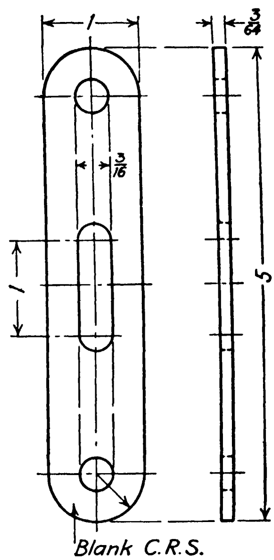


FIG. 37.—A steel "strap" that is perforated and blanked in the two-station die shown in Fig. 38.

Figure 40 shows the plan and front elevation views for a progressive die in which the blank shown in Fig. 39 is produced. The progressive cuts are divided between stations 1 and 2, so that die edges too near together are avoided. In station 1, a cold-rolled steel die block is used, because all the holes cut here are lined with tool steel hardened and ground bushings. This saves tool steel.

Additional layouts, illustrations, formulas, and detailed information for these types of press tools are given under the chapter entitled "Progressive Dies."

Finger Stops.—This die has two finger stops for starting in a new strip. In some shops, where experienced pressmen are employed, finger stops are frequently omitted. The operator is supposed to "sight" the strip end into proper position through a slot and scribed line on the stripper plate. However, this practice involves an unfortunate risk of positioning the strip wrong. This error may result in deflecting frail punches and fracturing cutting edges.

Piloting.—In station 2 the work is registered, when the ram descends, by four pilot pins that are tangent within the periphery of the large hole that was cut in station 1. In station 3, a large pilot on

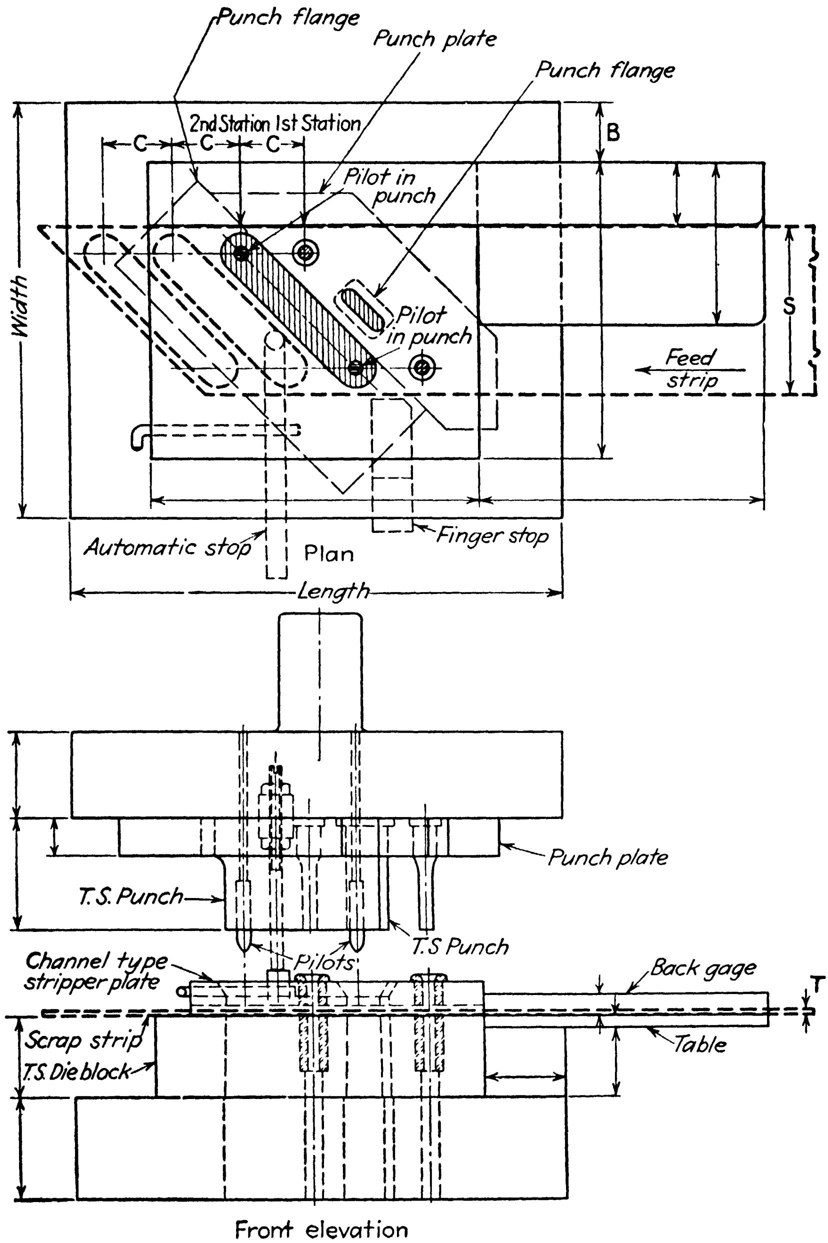


FIG. 38.—"Tandem" perforating and blanking punch and die for producing large quantities of the steel-strap blank shown in Fig. 37.

the face of the blanking punch registers the strip by entering the same hole.

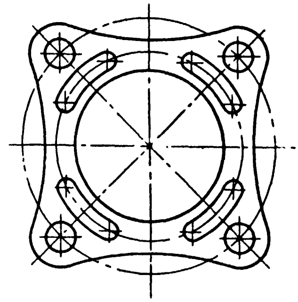


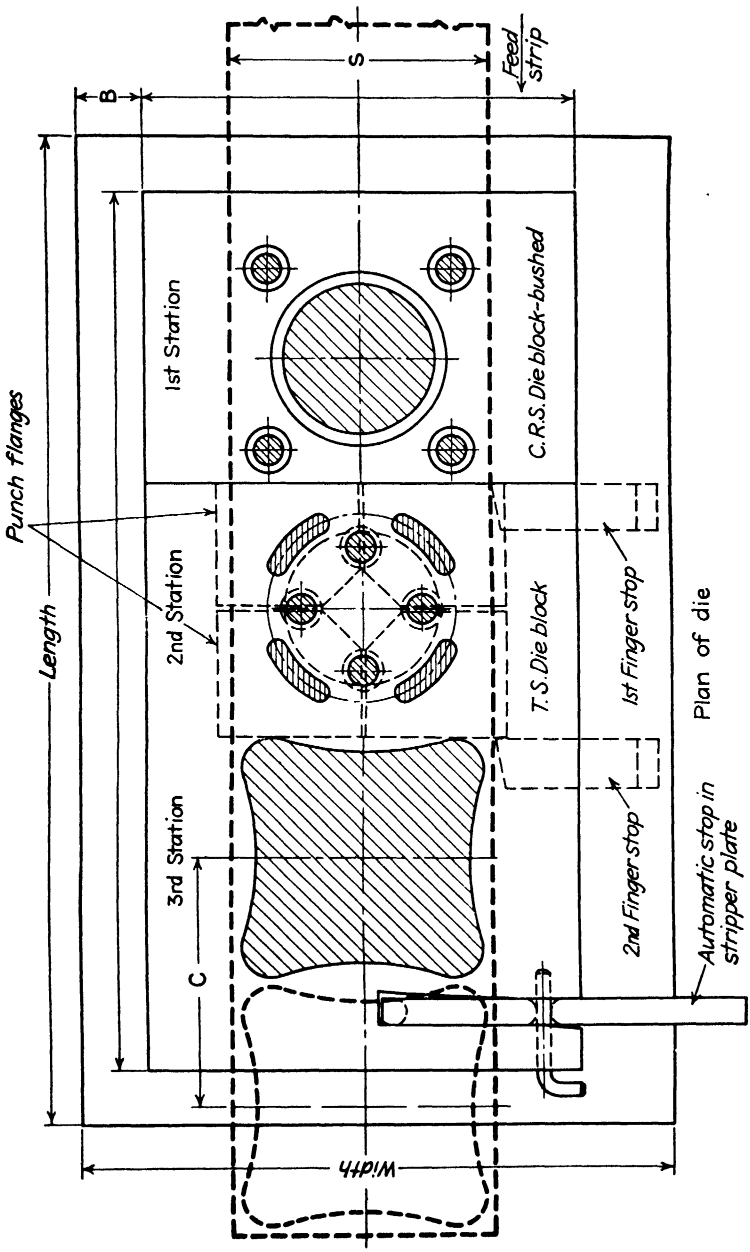
FIG. 39.—A heavy steel blank in which the edges of the holes are too near one another to be cut in one or two stations. We then resort to designing a progressive die, as seen in Fig. 40.

PUNCH GUIDES AND QUILLS

Drafting Technique.—The designing of unusual dies and difficult tools calls for careful engineering. First, the designer must get the right conception of what the new device is expected to do. He then makes a series of freehand "discussion sketches" leading up to the general scheme of the tool assembly. Next, a light-lined drawing is started in which the necessary details can easily be incorporated. The complicated details are handled the same as the general scheme, by making a sufficient number of freehand sketches to satisfy the design, then drawing the ones chosen into the general assembly. The work to be done is laid out in two or more views, using heavy dotted lines, preferably in red. The tool sketch is made in conjunction with these views. The tool is designed from its center out, and on both sides of center lines wherever possible.

Keeping Records of Failures.—It is just as important to know which designs will fail as it is to know which ones will succeed. For this purpose a helpful record can be built up through the years. Die engineers who have kept these records have found that about fifty varieties of die failures cover nearly all of them. They make written notations of the designs and types of constructions for individual parts of dies where failures have occurred, and refer to the tool drawing number where the trouble is shown corrected. They draw a little sketch and give a short description of the nature of the fault and how to avoid its reoccurrence. This information is used for reference. It is inserted in the shop standards book with which every designing office should be provided. But singularly enough it is sometimes found that a member which has failed to function in one tool design will work well in another. However, this is the exception rather than a rule.

Repeat Designs May Become Monotonous.—There are certain types of die design that a tool engineer should try to avoid. A few of the outstanding ones will be considered. A group of shops as a whole may produce a great variety of fabricated parts, but each shop may be using different types of die designs and construction, even for similar parts. This suggests that perhaps some shops con-



Feed strip
S
B
Punch flanges
Length
1st Station
2nd Station
3rd Station
C.R.S. Die block-bushed
T.S. Die block
1st Finger stop
2nd Finger stop
Automatic stop in stripper plate
C
Width
Plan of die

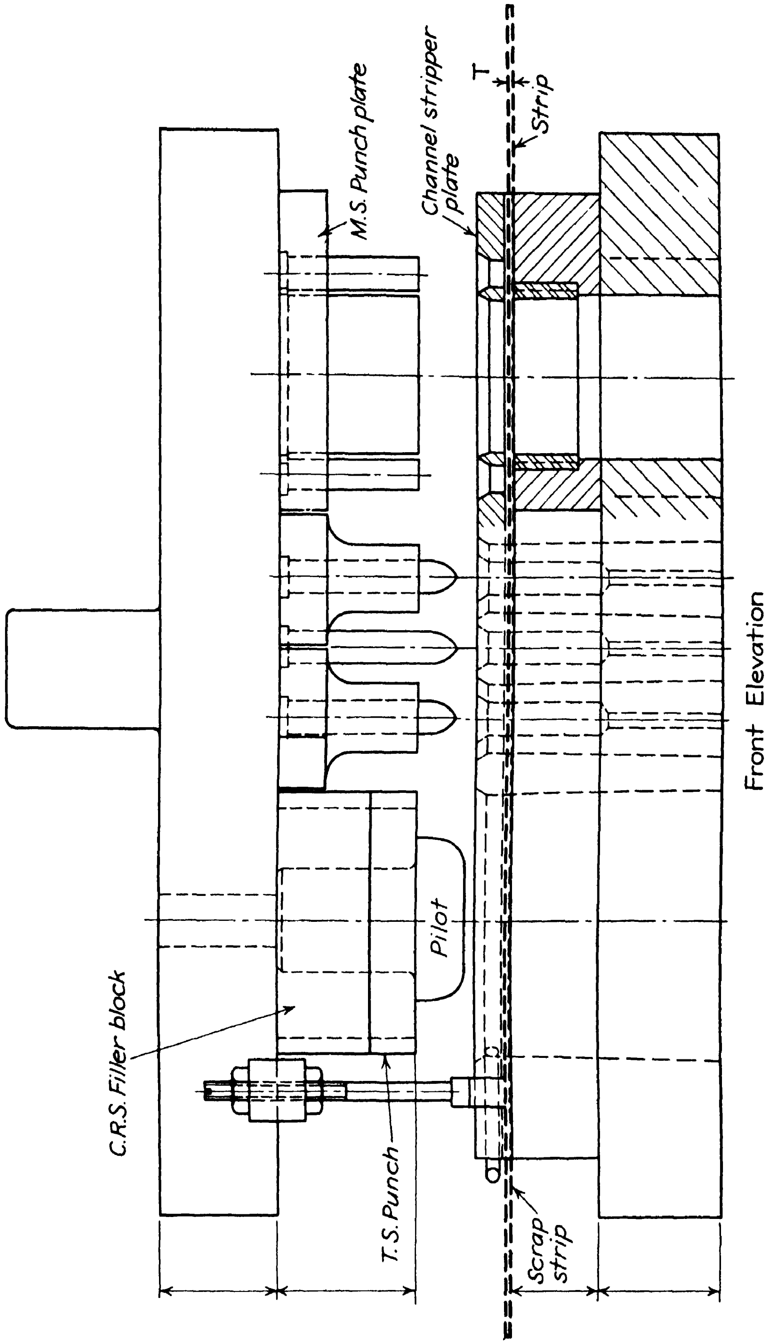


FIG. 40.—A three-station progressive die for producing the blank shown in Fig. 39. One of the die blocks is of cold-rolled steel. Drafting time is saved by showing the outlines of the punch flanges in dashed lines on the die plan. This saves drawing an additional view of the tool.

tinue to use certain types of their own tool designs too long. They get "the habit" by repeatedly following the old styles, and this finally leads into dull routine. But their competitors, having avoided this, may be doing similar work faster, cheaper, and better.

Trouble with Blanks and Slugs Adhering on Punches.—Small blanks and round slugs, which are cut from thin-gage materials, will sometimes fail to cling in the die for pushing through. This is especially true if the strip is lubricated. The lubricant creates a vacuum between the cut blank and punch face, and the blank then goes up with

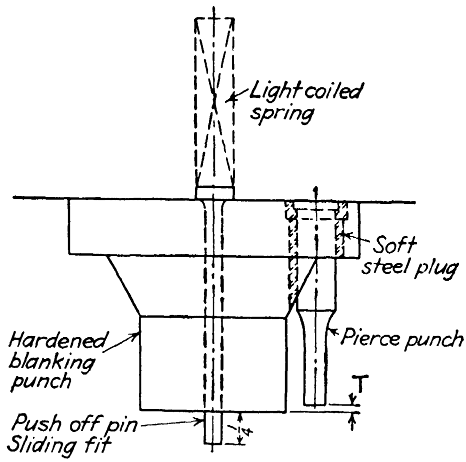


FIG. 41.—Push-off pins prevent cut blanks from leaving the die and following up on the face of the punch when it ascends. Small piercing punches close to a large punch are secured in hardened punch flanges by an inserted soft-steel plug. Such punches are made shorter than the large punch by distance T, which is the thickness of the material strip.

the punch when it ascends. Another cause of this trouble is inaccurate diemaking, the die opening being flared slightly toward the top of the block, instead of toward its bottom as it should be.

One remedy for this trouble is to provide a vertical "spring push-off pin" through the punch. The outer end of the pin extends $\frac{1}{4}$ in. beyond the punch face, Fig. 41. The pressure of the pin on the blank in the die causes it to remain there when the punch ascends. If a piercing punch is too small to insert a push-off pin, the face of the punch is ground cross-grooved, or with other indentations found by experiment, or with a slight convex point which will either break the vacuum or cut a slightly oversize slug that will stick in the die.

Slugs that follow up with the punch are very troublesome in progressive dies. Not only will they be jammed into the strip when the

punch descends with one, but they often loosen and fall on the strip or get under it, causing false gaging, miscuts, and slow production. In progressive dies where notches are cut in the sides of the strip, with punches having backing-up heels, if the notch is V-shaped, the scrap is very likely to come up with the punch. The cure for this is to use push-off pins, as just described, or to change the shape of the cut so that the slug has parallel sides that will stick in the die, or to cause the slug to fall out beneath the press by adjusting the ram so that the punches enter the die deeper. The designer must be fully aware of all these difficulties during the initial designing of the tool, or he must submit to final alterations by the toolmaker, who finds it necessary to correct the die for trouble-free production.

Troubles with Small Punches.—Small piercing punches with edges located by a space between itself and the edge of a larger punch—a space about $1\frac{1}{2}$ times the diameter of the smaller, or less—should be made shorter than the length of the larger punch. The smaller punch should be shorter than the larger by at least the thickness of the work material being cut, Fig. 41. The reason for this is that, when a large punch is cutting, the metal is forced into a plastic flow around the cut. This, of course, interferes with the free operation of the smaller punch if its length equals that of the larger. The smaller punch is caused to deflect and fails to enter the die properly. The results are clashed cutting edges, sheared and nicked punches and dies, and even sometimes the breaking off of a small punch, if its temper happens to be too hard.

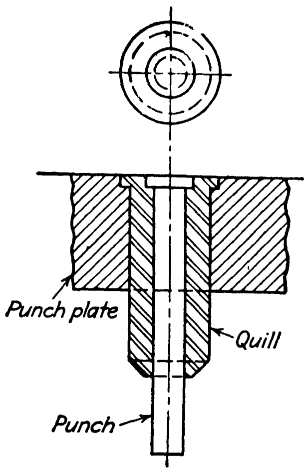


FIG. 42.—A frail piercing punch held in a quill can be replaced if broken, or another punch with a smaller piercing point can be substituted. In the latter case, the die bushing is also replaced with one that suits the new punch size, as shown in Fig. 43.

The old rule, that all punches of less diameter than the work-material gage must be guided through positive bushings, should be changed to include those diameters which are less than $1\frac{1}{2}$ times the material gage. To follow this rule would save replacing many broken punches.

Small Punch Held in Flange of Larger.—Small punches close to larger punches can be secured in a soft-steel plug inserted in the larger punch flange, Fig. 41. The small punch can then be located accurately, even though the hole in the flange has been distorted by hardening.

Quills.—A quill is a shouldered sleeve that is used to support and guide a frail piercing punch. The punch is a sliding fit through the center hole in the sleeve. It is an advantageous substitute for a solid punch. Figure 42 shows the simple construction of a quill with a punch inserted. If the punch becomes broken, or ground short, a

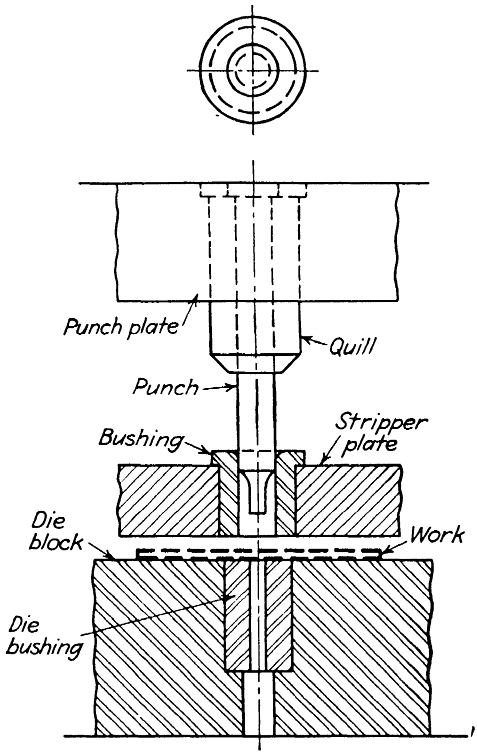


FIG. 43.—Showing a punch that has a short "stubby" point; the body of the punch is inserted in a quill. The result is better guiding of the punch point because the body of the punch is stiffer. Frail punch points can be guided in bushings of twice the diameter of the hole to be pierced.

new one can easily be "slipped" through the quill in place of the one discarded. In high-quality dies, quills are made of tool steel, hardened, ground, and lapped.

The head is turned on the punch as an integral part of its body; it should be a square-shouldered round head, as shown in the figure. This type of punch head holds more securely than one formed by upsetting the punch body in a countersunk hole. The latter types of heads often pull out of the quill when the punch is being "stripped" from the work.

In operation, frail punches may break at any time, even though guided through positive bushings. Especially is this so if the gage of the metal being pierced is equal to, or greater than, the diameter of the punch point. Frail punches will break if the physical properties of the work are highly resistant to shear, as when piercing steel or tempered materials.

Quills are usually mounted in individual punch plates when possible. The plate is secured on the punch holder with two screws and dowel pins. This construction permits an easy removal of the parts for replacements. In using quills, it is very easy to substitute smaller sizes of punches. The body of the new punch is made to fit the quill, while the punch point itself is reduced to a smaller size (See Fig. 43). A larger punch, up to the diameter of the punch body, can be substituted in the same quill. If a still larger punch is necessary, it is best to make a new quill. A required punch may be large enough to make its body diameter equal to the outside diameter of the quill; in that case the quill can be dispensed with entirely.

Guiding Frail Punches in Oversize Bushings.—Figure 43 shows the design for a punch point that is often resorted to in order to obtain a larger diameter for guiding the punch than when using the diameter of the punch itself. The length of the punch size is made short and "stubby" for extra strength. When the "life" of the punch has been used up by grindings, the old punch is removed and a new one substituted.

SIMPLE MATHEMATICAL FORMULAS

Secure Uniformity and Furnish Useful Data in Die Engineering

Channel Stripper Plates.—It is surprising how efficiently a thin positive steel plate will "strip" off the scrap around the punches in even a large blanking die. A plate of about one-half the thickness generally used will do the work. This does not refer to long progressive "cut-and-carry" dies, or to cases where thick plates are necessary for inserting shouldered bushings as guides for small piercing punches. The reference here is to plain blanking dies, and to progressively piercing and blanking when the piercing punches are sufficiently large to avoid the use of guide bushings. As mentioned elsewhere, bushings are unnecessary for guiding piercing punches when their point diameters are greater than 1½ times the thickness of the work material.

Channel types of positive stripper plates, which are secured over blanking dies with screws and dowel pins, are often made too thick, as shown by dimension *Y* in Fig. 44. This fault is responsible for subsequent troubles after the punches become too short (from repeated

grindings, section A-A) and fail to reach into the die openings beneath the stripper plate. If the remaining "life" in this die is to be used, it will be necessary either to remove the stripper plate and reduce its thickness, or to counterbore the holes deeper for all the screw heads, drive down the dowel pins, and then cut off the top surface of the plate. The worst part of the story is that all this unnecessary work could have been avoided by using a plate of the right thickness to begin with.

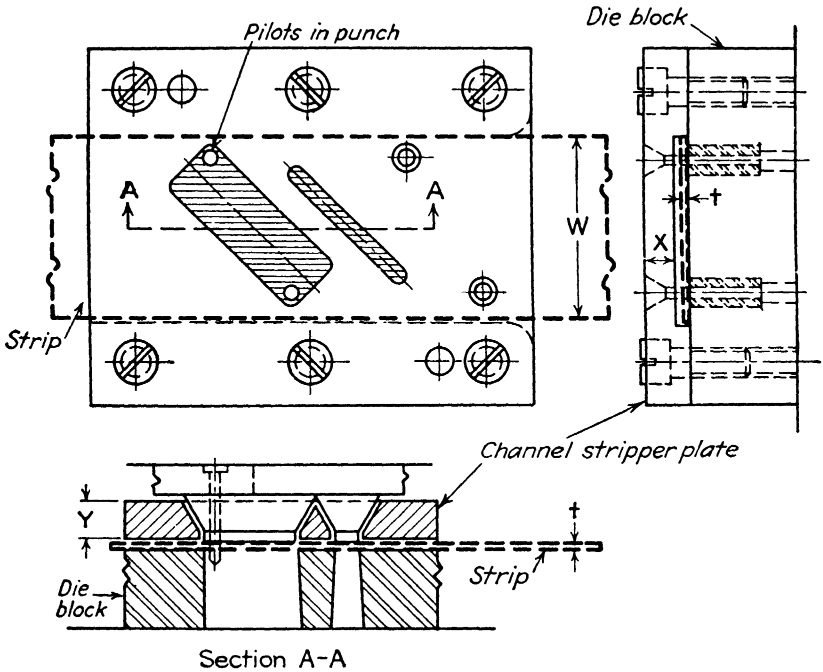


FIG. 44.—Section A-A shows that worn punches fail to reach the die if the stripper plate is made too thick; X illustrates the formula for determining the minimum safe thicknesses of stripper plates.

It is certainly not good tool engineering to guess the important sizes of die members, and then, when the tool goes wrong, attempt to justify the guess by saying, "the sizes seemed to be all right." There is a definite mathematical relationship between the thickness and width of a material strip and the safe minimum thickness of a stripper plate. The amount of stripping tonnage can safely be ignored in this relationship because it naturally becomes involved in the formula along with the different thicknesses and widths of the strip. The formula is illustrated at X, Fig. 44. In the formula all dimensions are in inches.

If t = thickness of material strip,
W = width of material strip,
X = thickness of stripper plate,
then

$$X = \frac{W}{30} + 2t$$

If the final result for X is in odd decimal parts of an inch, use the nearest thickness of cold-rolled steel which is an even ⅛ in. For plates that are wider than 12 in., use machinery steel finished to a thickness similarly obtained.

How Much Pressure for Stripping?—Stripping must be done when the punches ascend after they have cut through the sheet. The scrap around the punches is carried up until its top surface contacts under the "roof" across the channel of the stripper plate. In the formula for the required tons of stripper pressure, L and t are in inches.

If L = length of cut edge,
t = thickness of material strip,
S = stripping pressure in tons,
then

$$S = 1.75 \times L \times t$$

Elevated Stripper Plates.—These types of stripper plates can be used for disposing of cut blanks which have been ejected by a spring shedder in the die. To do this, the roof is made high enough to provide an interval of time in which the blank can be blown off before the roof "strips" the punches and the scrap falls down on the die. In such designs, the stripper plate may be mounted over separator blocks secured between it and the die block. By this design, the necessary space and time are provided in which to blow away the blank, as illustrated in Fig. 45. Sometimes this operation is done by using coiled compression springs over the plate. A shouldered screw is inserted through each corner of the plate, and a spring surrounds each screw. The punch, in ascent, carries up both the strip and plate into contact with positive stops. The blank is blown off the die just before the plate is stopped and returned by the springs.

Punch Plates.—Punch plates are usually made of cold-rolled steel, but many designers prefer to use low-grade tool steel and leave the plate soft. Tool steel is tougher than cold-rolled, and, after it has been machined all over and then drilled and counterbored for inserting the punches, the screws, and the dowel pins, it does not change its shape. On the other hand, cold-rolled steel is likely to distort somewhat after drilling and boring.

Punch-plate Thicknesses.—Figure 46 shows part of a punch plate with two different types of punches inserted. For small punches, thickness T of the plate should never be less than $1\frac{1}{2}$ times D, and

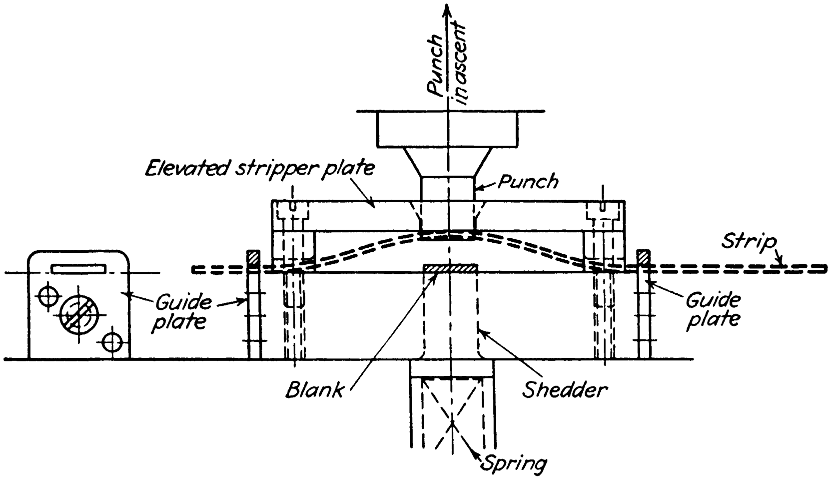


FIG. 45.—An elevated positive-type stripper plate that provides space and time for blowing away a blank with compressed air. The blank is ejected from the die by a spring shedder.

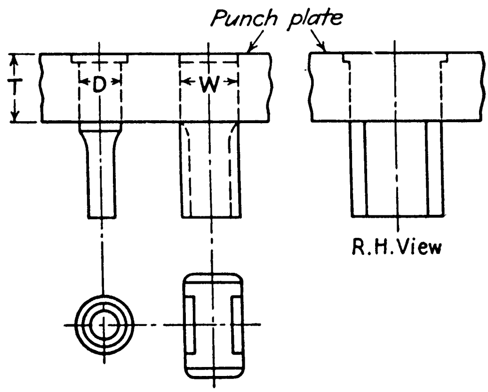


FIG. 46.—Illustrating the rule for using punch plates in which T is at least $1\frac{1}{2}$ times the size of either D or W.

the next higher thickness of the steel which is an even $\frac{1}{8}$ in. is the best size to use. If T is undersize, the punches will not be stabilized properly, will deflect when contacting the work, and will fail to enter straight into the die openings.

Punch Bodies.—It has been said that small rectangular punches "stand up" better if they are machined from a solid block and with a generous size of mounting flange for screws and dowel pins. However, this type of punch is not always feasible; there may not be sufficient space for mounting the flange, because other punches are too near. Figure 46 shows how this condition is avoided by using small shoulders on two opposite sides of a rectangular punch and mounting it through a punch plate along with other punches. Here again, T should not be less than 1½ times W, which is the width of the punch. When several punches are mounted in one plate, thickness T should be made to suit the largest size of either D or W.

Press Pressures for Blanking Operations.—The tons pressure required for cutting a blank is the product of the following terms: the total length of the cut edge in inches, multiplied by the material thickness in inches, multiplied by the ultimate shearing strength of the material in tons per square inch. If the blank contains round holes, or other openings which are cut simultaneously with blanking, the total lengths of these cuts should be added to the perimeter of the blank.

Capacities of Presses.—The safe capacity in tons for a single-crank press is the product of the following terms: 3½ tons, multiplied by the square of the diameter of the crankshaft in inches, taken at its main bearings. The same computation is also used for double-crank presses up to 9 in. diameter of shafts. Following this diameter, the double-crank strengths increase rapidly compared with those of the single-crank diameters, as the comparative diameters of the double cranks increase. It is always safe to use a press capacity considerably in excess of the computed pressure required for the operation, at least 25 per cent, or more. (See table at beginning of Chap. XVI.)

Pressures for Bending and Forming.—For bending, forming, or assembling, test the die for the operation in a hydraulic press having a dial gage that indicates the tons of pressure required.

Pressure for Drawing Shells.—The maximum pressure in tons for drawing a cylindrical shell is the product of the following terms: 0.00157, multiplied by the shell diameter in inches, multiplied by the material thickness in inches, multiplied by the ultimate tensile strength of the material in pounds per square inch. The diameter of a drawn cylindrical shell is its outside diameter minus the thickness of its wall.

How Much Punch Clearance?—Designing "trouble-free dies" calls for more thoughtful care and experience than just laying them out on paper in conventional form or making drawings of the proper technique. Especially is this true of very accurate dies for abnormally long blanks of thin-gage material, in which the punch clearances are neces-

sarily very small. Correct punch clearances are highly important factors in dies for precision work. Right or wrong punch clearances can easily determine the final success or failure of a tool.

Over-all punch clearances for accurate work are usually 5 per cent of the material thickness for brass and soft steel, 6 per cent for half-hard steel, and 7 per cent for hard steels. However, these percentages can be doubled when blanking heavy sheet in which burrs and slight variations in the work sizes are permissible.

For producing blanks of accurate contours, the die opening is made the exact size and shape of the blank, and one-half of the over-all punch clearance is removed all around the punch. For holes and other interior cuts through the blank, this rule must be reversed. The punch is made the exact size of the hole, and one-half of the over-all punch clearance is added all around within the die opening. For high-precision work, the size of the blank is *diminished*, and the sizes of the perforations through the blank are *increased* 0.001 to 0.002 in., over all. This is necessary because the blank expands and the holes close in approximately these amounts after completing the die operations.

A generous punch clearance greatly reduces the pressure load on the press. In some instances it may even permit running the job safely on a smaller press of higher speed. This is particularly true when the die face is sloped away from both sides of its center, thus producing a "shearing cut," as it is commonly called. The height of the shearing angle should not exceed the material thickness unless the finished work sizes are unimportant. A shearing cut reduces the press exertion about one-third.

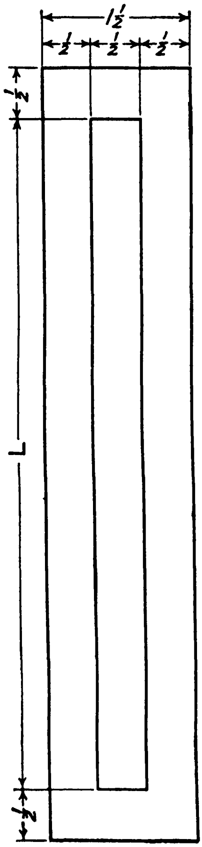


FIG. 47.—Illustrating some of the difficulties encountered when cutting long narrow hard-rolled steel blanks that must be free of burrs.

Long Blanks and Cutting Difficulties.—Two similar dies, taken from recent practice, show the necessity of using foresight in designing blanking dies for excessively long work. Figure 47 represents a blank of 0.0156-in.-gage, hard-rolled steel. This is a high-production piece of work. It is to be within fairly close limits, and with a minimum of burrs. The dies were designed to handle the work progressively, and with one "tripping" of the press clutch

throughout the entire lengths of strips 10 to 12 ft. long. In other words, the press was to be run "wide open."

There were two lengths of these blanks, one in which dimension L was 5 in., and the other with L equal to 8 in. The die for the shorter length was made first and was successfully operated at high speed. The second die, for the longer blank, although designed and built practically the same as the first, failed to work satisfactorily. The first

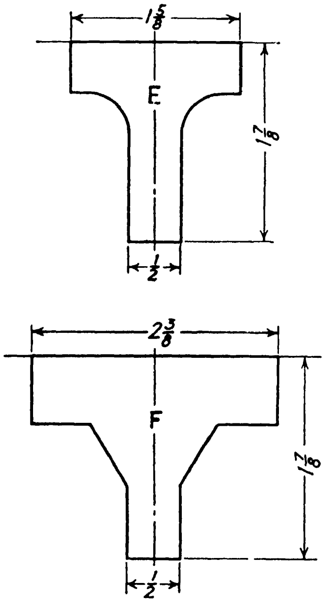


FIG. 48.—Long narrow punches will deflect while cutting hard strip and thus fail to enter the die correctly if the punch-flange width is insufficient. This fault is shown at *E*, and the correction of it at *F*.

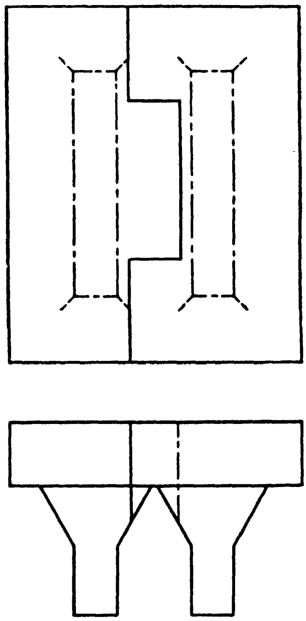


FIG. 49.—For long punches that are close together, extra widths of flanges for stabilizing their action are obtained by interlocking both punches.

die produced over 80,000 blanks before regrinding, but the second die failed to produce 10,000 without regrinding and showing several other faults. Both punches and dies were "flat faced." No shearing cuts were permitted. The punch clearance was 0.0005 in. on a side, which seemed very small but was according to standard. Punch clearances could not be increased because that would enlarge the burrs.

One of the difficulties in cutting the long blank will be seen at E, in the cross-sectional view of Fig. 48. The punches for both dies were designed and made as at E. This answered the purpose for cutting the short blank, but the $1\frac{5}{8}$-in. width of flange base was too narrow to suit

a similar punch for the long cut. The long punch blade would repeatedly deflect sidewise in cutting, and the slight punch clearance permitted edges to clash. Scored sides and nicked cutting edges were the result. The die sets were provided with four substantial guideposts and bushings, so that there was no trouble from that source.

Other difficulties encountered in the long die were corrected by introducing an idle station between the perforating and blanking punches, and by grinding the perforating-punch face $\frac{1}{32}$ in. shorter than the blanking-punch face. The latter change reduced the instantaneous cutting pressure and also avoided crowding of the metal between the punches. The longer punch was redesigned and given a wider flange base and a more "stocky" shape, as illustrated at *F*, and no further cutting difficulties were experienced.

Width of Punch Flanges.—In conclusion, the width of a punch flange should never be less than the punch height, and more than this is better if space permits. For long parallel cuts, depending on their widths and lengths, there should be one or more idle stations between them. While adding idle stations means using finger stops for starting the strip, if long coiled strip is used this is no serious objection. In close spaces, the advantages of having wider flange bases can be obtained by interlocking the punches as illustrated in Fig. 49.

CHAPTER III

PROGRESSIVE DIES

Progressive Slotting, Piercing, and Blanking Die

Design of the Die.—Figure 50 shows an assumed blank of hard-rolled steel 0.0375 in. gage. This particular blank gives us several conditions in the design of the die for producing it that we wish to consider. A three-station die for running this piece at high production is shown in the three views of Fig. 51. The usual drafting technique for presenting die drawings is also seen in this figure. Screws and dowel pins are omitted in the drawing, but care is used to design all of the members large enough to include them in the tool.

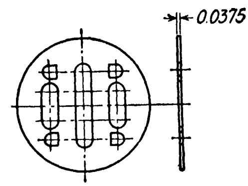


FIG. 50.—A hard rolled-steel disk containing slots and holes. This piece is scheduled for mass production.

The design and construction of this die must be A-1 and "trouble-free." It must be strong enough to stand up under long, severe, and continuous runs. To meet these conditions, the first step is to select an all-steel die set having four guideposts with special-composition phosphor bronze guide bushings. The guide bushings are extra long to prevent them from leaving the ends of the posts at the top of the press stroke. They also provide a sufficient space *E* in the punch holder to carry a continuous supply of lubrication.

In the plan view, the stripper plate is omitted for clarity, and all the die openings are section-lined to distinguish them easily. This die is composed of five sections, shown at the right, and the blanking-die block, shown at the left. Socket-head screws are tapped into all of the die members, and their heads are counterbored into the die shoe from its underside. At least two dowel pins are driven through each piece and into the die shoe. The diameter of dowel pins should not be less than the diameter of the screws that hold the pieces, and the screws should be "snug fits." Some diemakers make special screws of great accuracy for assembling die parts.

The die sections are sunk into the shoe and are held firmly together by the two wedges shown. The wedges prevent the sections from spreading while the die is cutting. Strip *C* is inserted as a measure of

precaution. If, in the final assembly, the sections should vary in length, this strip can be altered in width to suit conditions, and the die stations thus can be brought into line. The die sections are divided so that one-half of each die opening is located in opposite blocks; this is

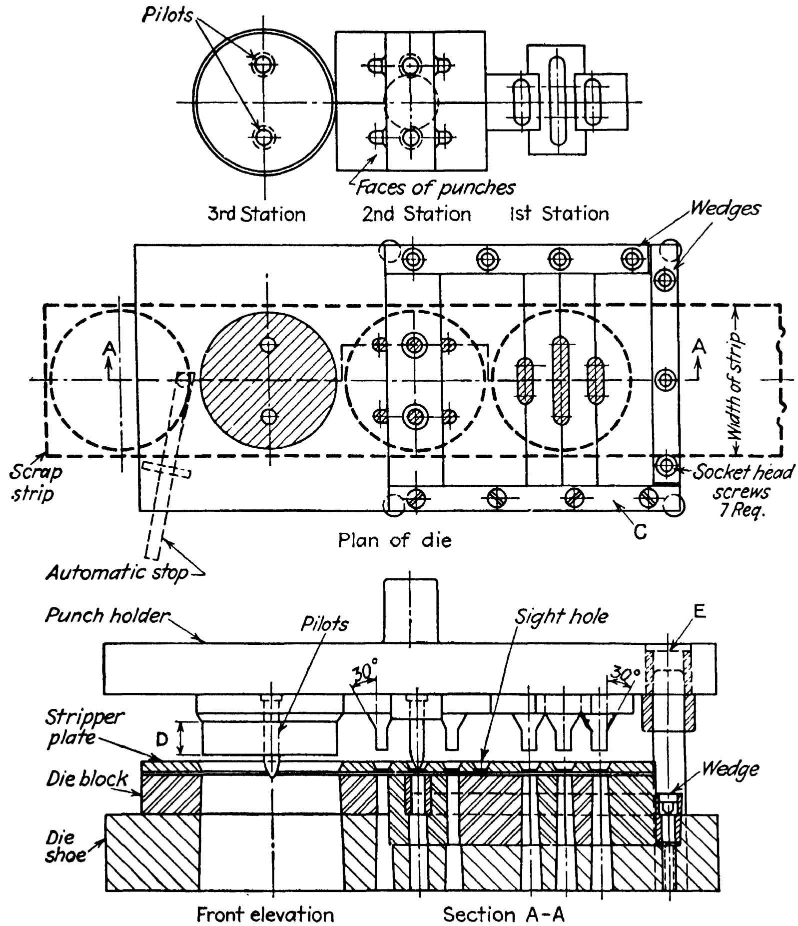


FIG. 51.—A typical high-speed progressive die for producing the steel disk in Fig. 50. Notice in the first station, above the die, that the flanges on the two smaller punches interlock into the flange of the larger punch. This permits the use of wider flanges and thus increases the stability of the smaller punches.

for ease in grinding the die interiors. In stations 2 and 3, two bullet-nosed pilot punches are located in each. These pilots enter the ends of the long slot, which was cut in the work at the first station. The pilots ensure that the strip is registered correctly at each descent of the punches.

Finger Stops.—For starting in the strip, finger stops can be omitted if the strip is of light-gage material. The strip is advanced under the stripper plate until its forward end coincides with the center line marked across the bell mouthed "sight hole" shown through the stripper plate. After cutting the first station, the strip is advanced with its forward end at the right edge of the blanking die opening. Next time the ram descends, the bullet-nosed pilot points enter the ends of the slots and register the work correctly. The next advance carries the strip into contact with the automatic stop, and thereafter the job is ready to be run at high-speed production.

Whether finger stops are necessary depends largely upon the care and intelligence used in the pressroom. But even finger stops are not entirely "mistake proof." The strip can be passed erroneously by the first stop and registered against the second stop; the press treadle can be "tripped," the clutch engaged in action, pilots smashed, and die blocks fractured.

Design of the Punches.—The punches are stiffened by the 30-deg. reinforcing angles shown on both their sides. The width of the punch flanges must be at least as great as the over-all lengths of the punches. This precaution prevents the deflection of the punches while they are in operation and thus avoids shearing or nicking the cutting edges.

Four punches for cutting the small holes are seen in station 2. Each of these punches is machined from a solid block of tool steel. This design is much better than attempting to use round punch bodies with shouldered heads held in a punch plate and kept from turning by the insertion of "dutchmen" dowel pins. Punches of this latter design should never be used in A-1 dies as they are very likely to loosen, because of vibration, and turn. Solid punches, with flanges large enough to admit two screws and two dowel pins, are the best for safe and sane construction. Note that the punch bodies and flanges are connected by a 30-deg. slant of metal. This design is stronger and better than using the conventional radius.

In stations 2 and 3 the pilot punches have square-shouldered heads. The heads are seated in counterbored holes. Round piercing punches should always have such heads; they prevent the punches from pulling out when stripping. This is a trouble that will surely happen if the heads are merely "peened" into a countersunk hole in the punch plate.

The Die Steels.—All the cutting steels in a die of this character should be a good grade of high-speed steel. In larger dies, a saving of steel can be made by facing the punch with tool steel, as seen at *D*. The filler block behind the facing is cold-rolled steel. In very large

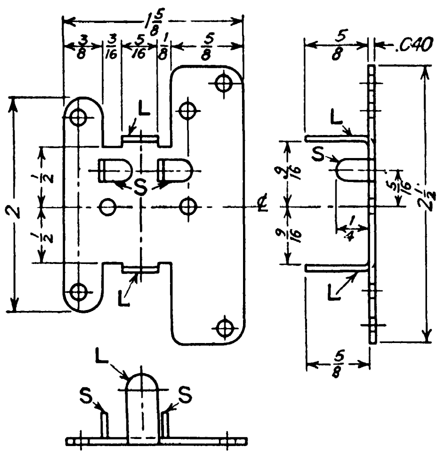
dies, the punches are built up with tool-steel sections that surround a machinery-steel center core.

Material cost for most dies is only about 5 per cent of the total. The greatest cost is time and labor. Cheap cutting steels have no legitimate part in "trouble-free" tools. They save very little labor cost, cause serious tool failures, hold up production, and may finally interfere with the promised delivery of the product.

PROGRESSIVE DIE FOR FIVE OPERATIONS

This Tool Notches and Outlines the Blank, Pierces Seven Holes, Bends up Two Legs, Shears through and Forms up Two Short Lugs, and Cuts off and Ejects One Finished Piece at Each Stroke of the Press

General Description of the Die.—Like most types of progressive notching dies this tool is a high-speed producer. It is used in a No. 3 press having 130 strokes per minute, and completes over 7,500 pieces per hour.



The Work

FIG. 52.—Specifications for a rear mounting plate used in a clock. This part is of 0.040-in. sheet zinc.

Figure 52 is a sketch of the workpiece which is the rear mounting plate used in the assembly of an electric clock movement. In Fig. 54 is the front elevation of the tool, while Fig. 53 shows the plan of the die.

The material strip is fed from right to left through table guide *A*. It enters the die under a positively attached channel stripper plate *B* and is advanced until the forward end of the strip contacts a finger stop (not shown) on line *C* in the plan.

In this first station, when the punches descend, two opposite notching punches outline the blank at both sides of the strip, and seven small round punches pierce the holes shown in the die in Fig. 53.

Notching Punches Must Have Back-up Heels.—As is usual in the design of notching dies, the notching punches are made with backing-up heels as seen in the detailed sketch of the punch. The heel on the punch enters the die opening ahead of the cutting edge and thus protects the sharp edges from shearing off or nicking, as might otherwise be expected from an unbalanced cut. The heel guides the punch into the die, preventing punch deflection and probable damage when taking "biting-in" notching cuts.

"Bushing" the Holes.—Three of the round holes in the die block are "bushed," and all the round punches and pilots are guided through shouldered bushings press fitted in the stripper plate. If space permits, all the round die holes in a first-class press tool should always be "bushed."

Pilots Register the Work.—After the punches ascend, the strip is advanced again until its forward end is "sighted in line" with the left edge of stripper plate *B* over die block *D*. At this station, when the punches descend, three pilot punches enter previously pierced holes in the work at the locations shown in the plan. The pilots align the work in all directions and thus ensure accurate stampings.

Running the Press "Wide Open."—The job is now ready to be run with the treadle of the press "open," that is, with the pedal held down continuously until the entire material strip has been fabricated into finished pieces.

Completion of the Work.—The final stop block is shown at *E*, and the blanking centers between stations are 1.625 in., the width of the blank. After the forward end of the strip contacts block *E* and the punches descend, the blank is severed by punch *F*, which shears off the piece on the left edge of the die block as indicated by the words "cut off" in Fig. 53.

Continuing in descent, punch *F* securely holds the cut-off blank between its face and the surface of spring pad *G* and within the parallel confines of the 1.625-in. dimension given in Fig. 54. Right- and left-hand punches *H* are positively attached on the die shoe, as are the two shearing punches *J*. These four punches protrude above the spring pad in its descent, and punches *H* bend up lugs *L*, $1\frac{1}{8}$ in. between, while punches *J* shear through and form up lugs *S* into the two die openings *M* in punch *F*. Lugs *L* are formed against the sides of punch *F*, which is 1.125 in. thick. Lugs *L* and *S* are shown in Fig. 52.

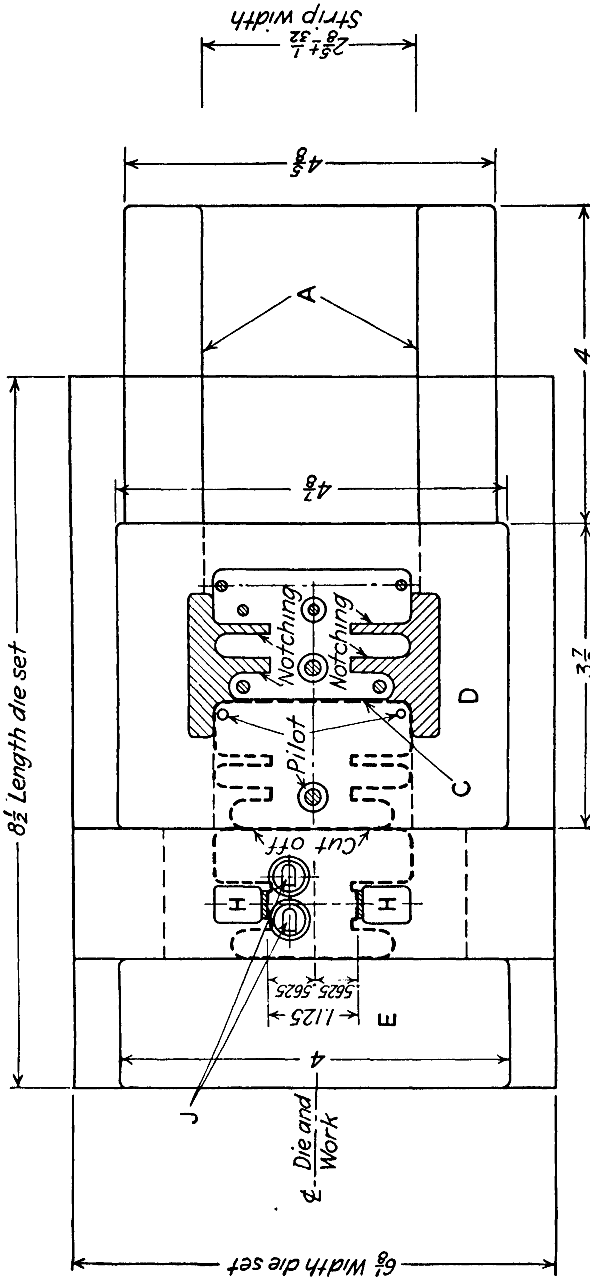


FIG. 53.—Plan view of the front elevation of the die shown in Fig. 54.

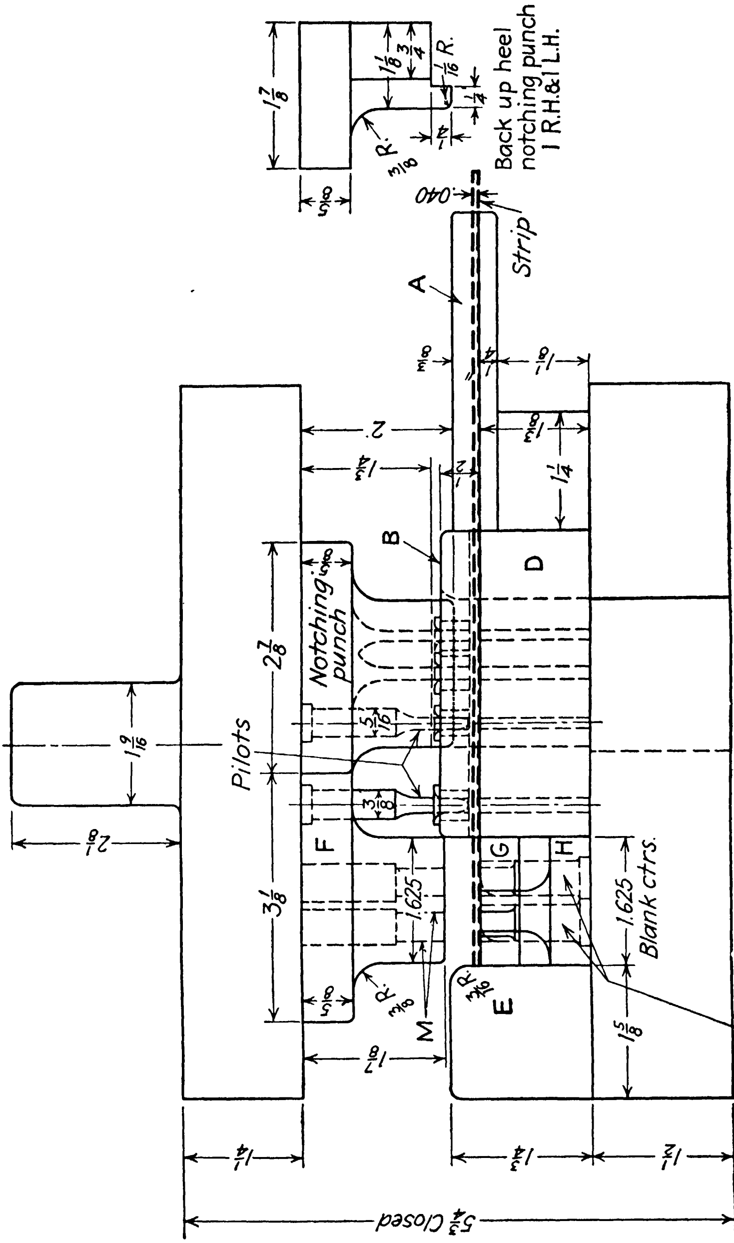


FIG. 54.—Front elevation of the progressive die that completes the part shown in Fig. 52 in one press stroke. This is a mass-production job.

At the completion of the press stroke, spring pad *G* positively stops against the flanges around punches *H*, and thus "spanks" the four upturned lugs square with the surface of the finished piece.

When the ram ascends, the spring pad follows up the work and punch until the pad face stops at its normal position flush with the die face. The piece is "stripped" from punch *F* by two spring "push-off pins" inserted through the punch, but not shown in the tool sketch. The press is used in its inclined position, and the finished pieces fall behind the machine into a suitable container.

Progressive Die Combined with Auxiliary Dies.—This type of progressive die has been successfully used in the high production of aluminum primer caps. The auxiliary punch and die is an independent unit secured crosswise to the main die and next to the last station in the die shoe. The main dies are composed of a series of punches mounted on the die shoe and surrounded with stripper pads; compound dies are aligned above the punches and mounted on the punch holder.

The auxiliary, or unit die, cuts round disks from a thin narrow strip of tinfoil that is fed by a small reel behind the unit. The punch in this unit pushes the cut disk down over a small hole, which has previously been pierced in the end of each primer cap and has been automatically dabbed with glue. In the down stroke, air pressure is introduced through a hole in the punch that blanks the tinfoil disk. The air forces the disk to adhere over the glued hole in the primer cap. Without the air pressure, the disks fail to adhere on the caps; on the contrary, the disks invariably follow the punch ascent. Each cap must have a disk pressed over its end.

Other designs for the auxiliary-die blank may be used. The blank may be made with clinchers, or it may be the blanking and drawing of a very small shell that can be pressed into an opening in the part made in the main die, when the work halts under the auxiliary-die station.

This die is run in a 50-ton-capacity press. The aluminum strip is fed from a coil of stock mounted on a reel. The strip is passed over the dies by contacting between a pair of revolving feed rolls that are mounted in front of the receiving end of the die, between the press and reel.

MASS-PRODUCTION DIES FOR SMALL METAL PARTS

A Typical Progressive Die

Dies for High-speed Production.—The demand for quantity production of small metal clips, spring jacks, and terminals used in radio equipment and for articles sold in 10-cent chain stores has attained enormous proportions. Conditions today have added to the list the

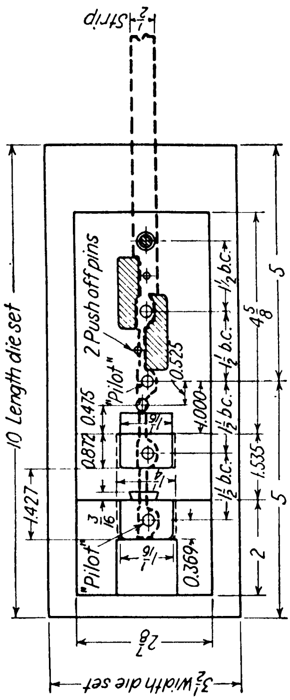
multitudinous parts used in war equipment. To meet this demand, it was apparent long ago that a new technique in the design and operation of press tools was needed. The old method of blanking pieces through the die and then rehandling them several times in forming operations was too slow, wasteful of material, and costly. Obviously, a better procedure must be found.

High-speed Presses, Reels, and Hitch Feeds.—The solution of this problem began with the advent of the Multislide machine. This machine could not be profitably operated without using long strips of sheet metals. The strip-producing mills responded by furnishing strips in large rolls of ligl t-gage materials, and to specified widths. Improvements in ball-bearing reels for handling the coiled strip immediately followed. To this were added more improvements in feeding equipment. One of them is a "hitch-feeding" mechanism, fastened on the shoe at the right of the die, through which the strip enters the press tool. This device is provided with a "jackknife" feeding jaw and a check jaw. It is actuated by a contacting lug secured on the punch holder, and advances the strip on exact blanking centers at each ascent of the press ram (see Plate XVIII, page 425.)

Useful Accessories.—There are other convenient accessories such as improved straightening rolls, strip centralizers, oilers, scrap bundlers and reels, and cutters for chopping the scrap, if any, into short lengths as it passes out of the die. Anything to improve conditions in handling scrap is very desirable. Large unwieldy piles of waste material in the pressroom become a serious problem when a score or more presses are each producing between 4,500 and 7,500 blanks per hour.

The Scrap Strip Determines the Die Design.—When designing a die used for any ordinary punch press, and for producing small parts, first develop the blank dimensions, and then adopt a width of strip equal to the length or width of the blank. This depends upon whether it is the length or width of the blank that extends across the strip. It is seldom necessary to run the blank bias to the strip length in these types of dies.

There are cases where the cross-strip dimension of the blank is in odd thousandths of an inch, and it is necessary to trim the strip width to blank size. This is done by notching punches placed on one or both sides of the strip, as described later. Next, determine a dimension for the blanking centers and draw an accurate layout of the scrap, giving the important dimensions. If the piece is small, it is best to draw the scrap strip to a scale of five or ten times full size. When this is done, fully 50 per cent of the entire tool design has been completed. With these data established, all that remains is to draw a plan of the


Strip
10 Length die set
2 Push off pins
"Pilot"
0.525
1.000
0.872
0.475
1.427
3/16
"Pilot"
0.369
1½ b.c.
4 5/8
5
1.535
2
2 7/8
3½ Width die set

PLAN

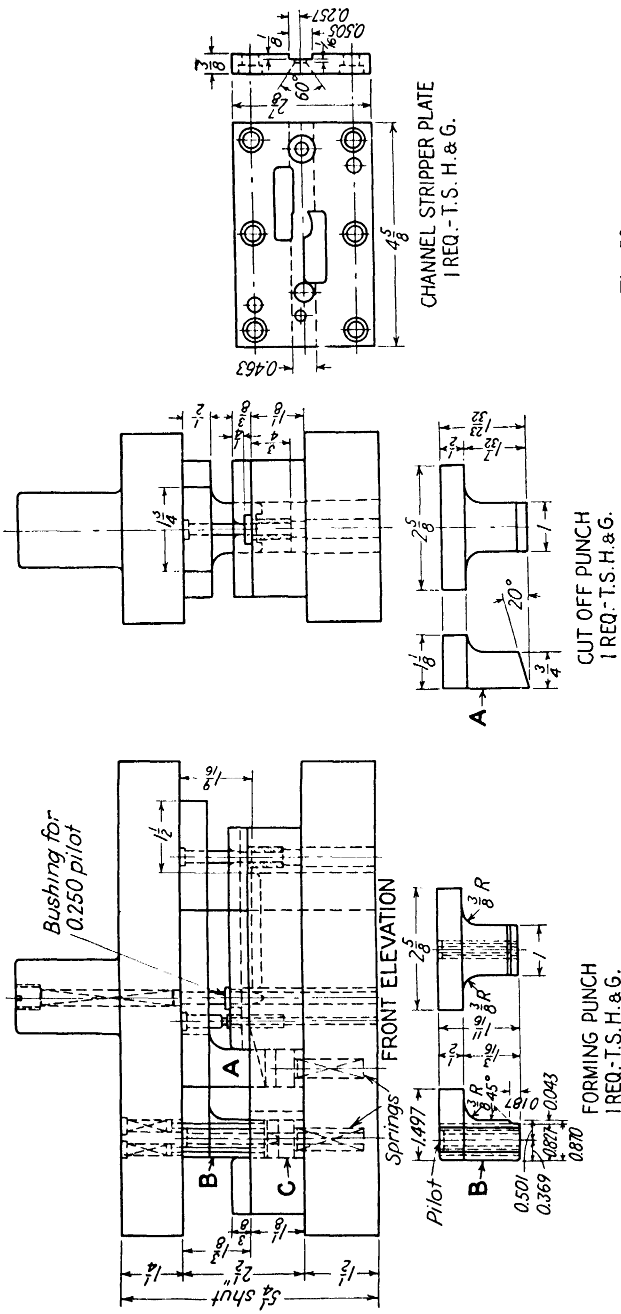
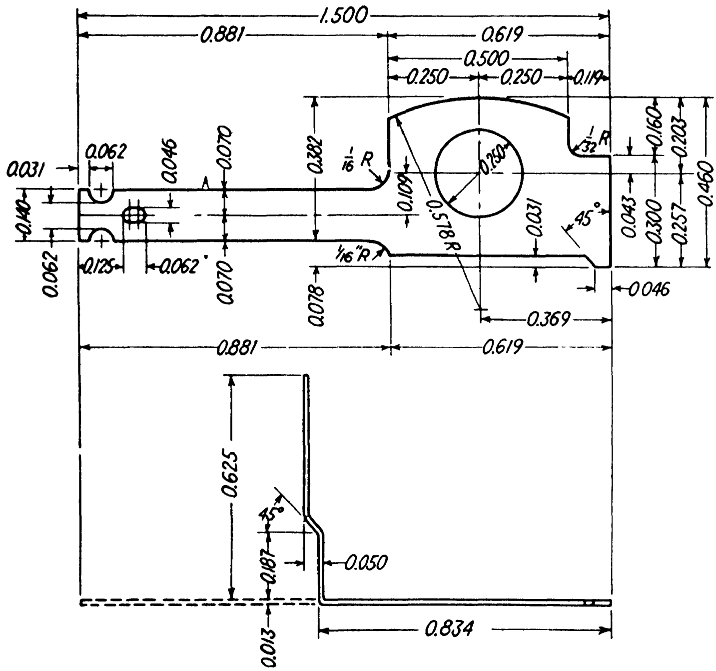


FIG. 55.—A high-speed progressive die for producing the flat spring blank shown in Fig. 56.

die, with a front elevation of the tool beneath it, and to select the die set.

Notching Punches.—For shaping the blank, it is customary to use notching punches with backing heels that enter the die outside the strip. These punches have such contours that, when they descend into the dies, the blank outline is cut from opposite sides of the strip, while the cut scrap passes through the dies.



#28 B.& S. (0.013") TINNED BRASS

FIG. 56.—A contact spring to be made in mass production.

A neck, usually ⅛ in. wide, is left between the notching punches to connect the blank and strip. This feature allows the strip and blank to be moved ahead into subsequent stations, when feeding occurs. The neck is cut away at the last station. The blanking center distance should be equal to the longitudinal dimension of the blank, plus the length of the neck.

Piercing and Stripping.—If holes must be pierced, it is done at station 1, previous to notching. The pierced holes are later engaged by a pilot punch to ensure registering of the blank at subsequent forming and drawing stations. A channel stripper plate is used and is positively attached on the die block. The channel width is made 0.004 in. wider than the maximum width of the strip; this provides for

passing the strip over the dies while it is practically centralized across the die openings.

"Push-off Pins" and Idle Stations.—At the centers of drawing and forming stations, a spring-actuated pushing-off pin is employed, either in the upper or lower dies, depending upon where the work is most likely to adhere after the operation. The push-off pin frees the work so that feeding may continue. It is sometimes necessary to provide an idle station, where no operation is performed, just previous to the last operation. The purpose is to obtain more space for attaching the

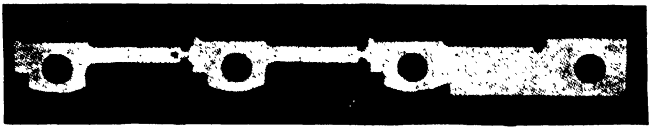


FIG. 56A.—A photograph of the strip produced by the die in Fig. 55, before the work is sheared off and bent.

cutting-off punch, or possibly a spring pad, or to provide more die steel for additional strength between the last two operations.

Sketch of a Progressive Die.—Here is a sketch for a typical high-production die, showing a contact spring, with the die and scrap strip, in Fig. 55 and the piece in Figs. 56 and 56A. This is a four-station die. Beginning at the right end of the die, in the first and second stations, the blank is notched to shape and pierced when the punches descend. In the third station punch *A*, in descent, severs the blank from the strip, while punch *B* in the last station forms up the terminal end 0.625 in. high against spring pad *C*.

PRODUCING WORK PROGRESSIVELY IN COMPOUND DIES

This Tool Pierces Four Holes, Cuts the Blank from the Strip, Pushes the Blank Back into the Strip, Forms Three Wings on the Piece, Pushes the Formed Piece Back into the Strip, and Finally Ejects the Finished Work through the Strip and Die, All in One Press Stroke

The Work, the Output, and the Die.—In Fig. 57 we have the specifications for a three-winged clip which is used in large quantities. This press tool completes one piece at each press stroke, or 7,500 clips per hour. The die design is illustrated in Fig. 58, where the plan and front elevations of the tool are drawn.

This is a six-station die, but stations 3 and 5 are inactive. An idle station is often necessary in progressive dies which have close centers between the stations. In this die, not only do the close centers make idle stations necessary, but the blanked opening in the strip is used to retain the pieces after cutting them out of the strip. In this way,

when advancing the strip, the idle stations carry the pieces into the station ahead for the next operation.

Handling the Strip.—The strip is fed into the dies from right to left. It unwinds from a stock reel placed near the side of the press. A hitch-feeding device attached on the end of the die shoe (not shown) advances the strip between die centers at each ascent of the ram. The end of the strip is started into the dies against the finger stop. When the ram descends, four holes are pierced in the first station. When the ram ascends, the material is stripped off by the action of a spring stripper plate, through which the punches extend. The pierced holes

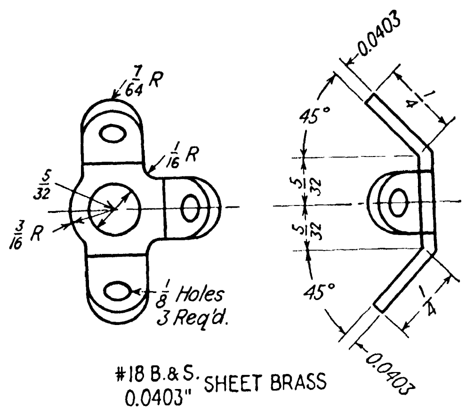


FIG. 57.—Specifications for a three-winged terminal clip.

and strip are then advanced into station 2. In the next descent of the ram, Punch *A* cuts the blank out of the strip. The pilot pin shown in the punch engages in the 5/32-in.-diameter hole previously pierced in the strip, and thus centralizes the cutting of the blank into the die. The hitch-feeding device is shown on Plate XVIII, page 425.

The Shedder and Stripper Plate.—The die opening is fitted with shedder *B*, which receives compression power from spring *C*. The spring rests on spring plate *D*. When the blank is cut through the strip, the shedder under the blank is depressed, and when the punch ascends, the shedder carries the blank up under spring compression and pushes it back into the blanked opening in the strip from whence it came. Spring stripper plate *E* holds the strip down on the die while the blank is being pushed in. As the ram continues to ascend, spring plate *E* strips off the work material around all the piercing punches.

Stations 3 and 4.—In the next advance, the cut blank is retained in the strip and is carried into station 3, which is inactive, as previously explained. After the punches ascend again, the retained blank in the

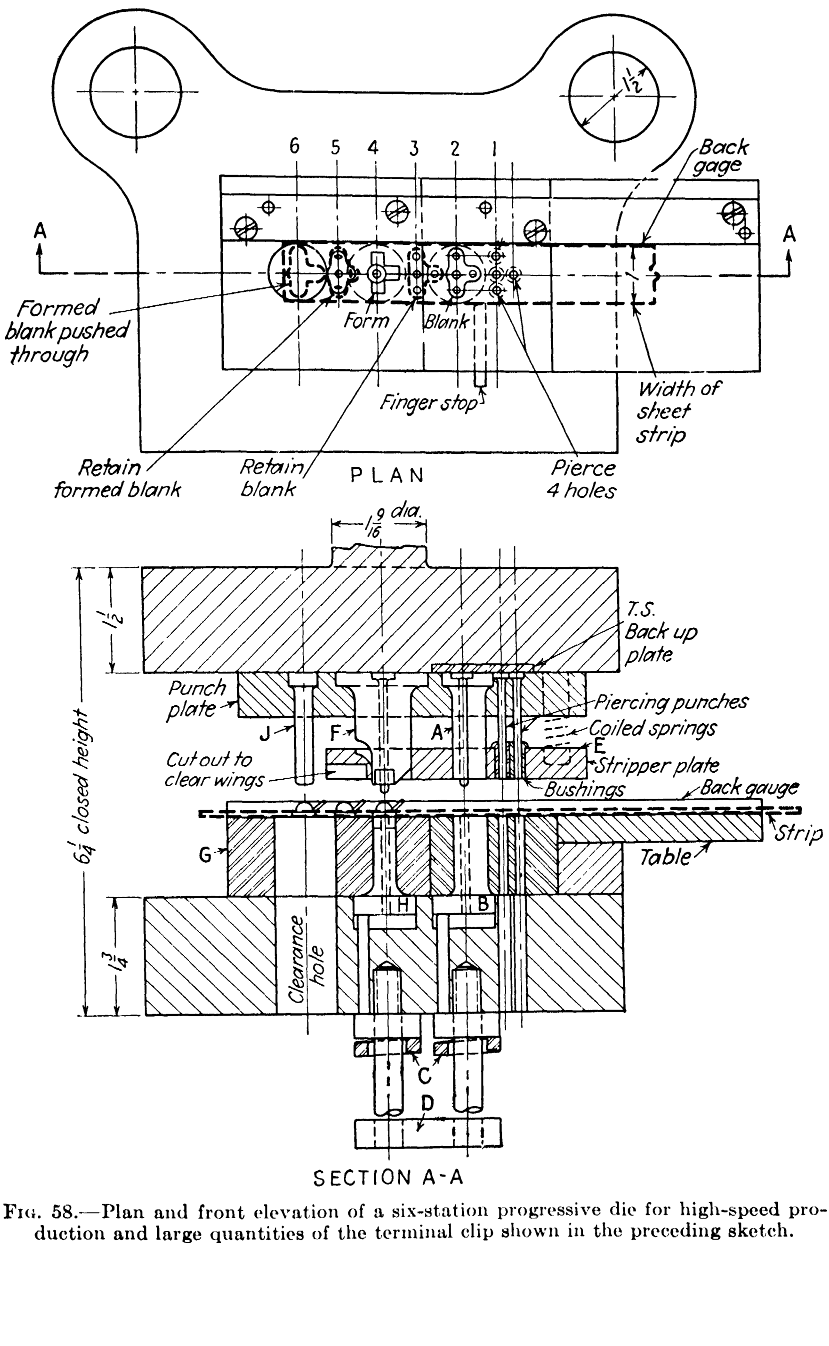


FIG. 58.—Plan and front elevation of a six-station progressive die for high-speed production and large quantities of the terminal clip shown in the preceding sketch.

strip is advanced into station 4 where the three wings are formed up. This operation is performed by punch *F* when it descends on the blank. The face of this punch has 45-deg. angular cuts on three of its sides. These cuts correspond with the widths and positions of the wings on the work (see Fig. 57). A pilot pin, which projects at the center of the punch, engages in the center hole of the piece and holds the blank central while the forming is done.

The workpiece is formed in die block *G* within three interior angles cut in the face of spring shedder *H*. The shedder and punch-face angles correspond with those on the work piece. When the ram descends, punch *F* pushes the work out of the strip and forms up three wings between the angles on the punch face and those in the shedder.

When the punch ascends, spring shedder *H* follows it up and pushes the formed piece back into the strip a second time, as was done at the blanking station. The work fortunately has a peculiar outline that makes this possible. It is retained in the strip the second time by the surrounding radii of $\frac{1}{16}$ and $\frac{3}{16}$ in. shown on the piece.

Stations 5 and 6.—In the next advance of the strip, the formed piece is carried into idle station 5. From there the piece, still retained in the strip, is advanced centrally over the large clearance hole in block *G*. This is station 6. When the ram descends again, punch *J* pushes the piece out of the strip, where it falls through the clearance hole in the die and die shoe and then into a chute leading to a suitable container.

Press Tools Should Be of Heavy Sections.—The reader will observe that the construction of this tool is comparatively heavy. Punches and dies are percussion tools. They must stand up and work after taking millions of hammering blows from a high-powered press. In designing press tools the foregoing statement should be remembered. All the working parts, and especially the cutting, drawing, and forming members in press tools, are of greater cross section than the parts in other types of tools.

ADJUSTABLE PROGRESSIVE DIE FOR CUTTING METAL BOX BLANKS

A Press Tool Having Movable Cutting Members for Producing a Large Range of Blank Sizes Is Described

The Sketch, Blank, and Strip.—The front elevation and plan view of this tool are shown in Fig. 59. One of the blanks produced is dimensioned in Fig. 60 and is one of many different sizes made with this tool. The width of the material strip is the same as the length of the blank and for the blank shown is $7\frac{25}{32}$ in.

Feed Table.—The feeding table *A*, of cold-rolled steel, is attached on a block mounted on the shoe. Over the surface of this plate, the

strip is advanced, from right to left, into the dies. An adjustable strip gaging block *B* is mounted across the rear end of the table and slides in the two elongated slots. This gage is adjusted to suit the width of the material strip and is then securely fastened by tightening the two nuts and bolts shown through the block and in the slots.

Perforating the Square Holes.—Two diagonally positioned square holes for the 90-deg. notches, which are corner clearances for folding the box, are pierced in both edges of the blank in die blocks *C*. The subsequent cutting off across the strip occurs on the diagonal center line of the square holes, thus leaving half of the hole, or the required notches, in both edges of the blank.

Adjustable Features.—Die blocks *C* are adjustable in two directions, namely, to and from each other in a cross slot, and because the blocks are mounted on the adjustable plate *D*, they can also be moved with it, either toward the right or left, while the attached gibs *E*, on the plate, slide in the slot guides *F*. The die blocks are fastened by tightening nuts *G*, and plate *D* is secured by tightening nuts *H*.

The piercing punches *I* are similarly adjusted by sliding the blocks *J* and *K*, to which they are attached. Tightening nuts, not shown, are provided for securing the punches directly over the piercing dies.

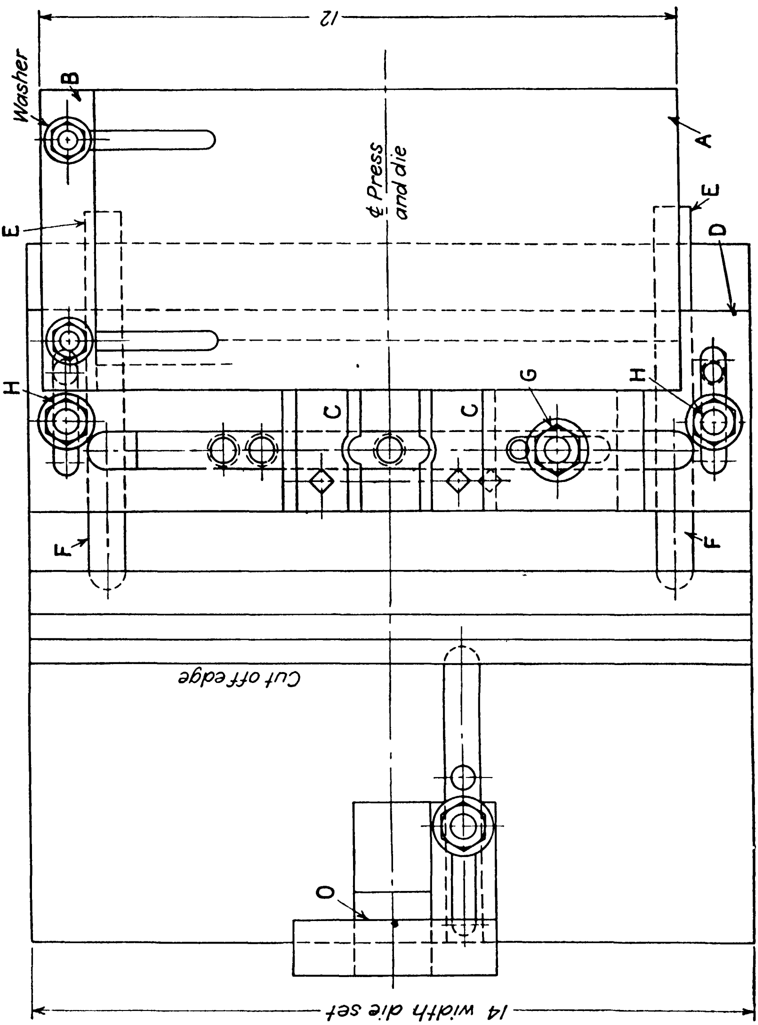
This two-way adjustment was the principal feature in the success of this tool. It is a principle that can be practically applied in a large number of adjustable dies made for any purpose.

After the punches descend and pierce the holes, the spring pad shown at *L* strips the blanks from the punches, when they ascend.

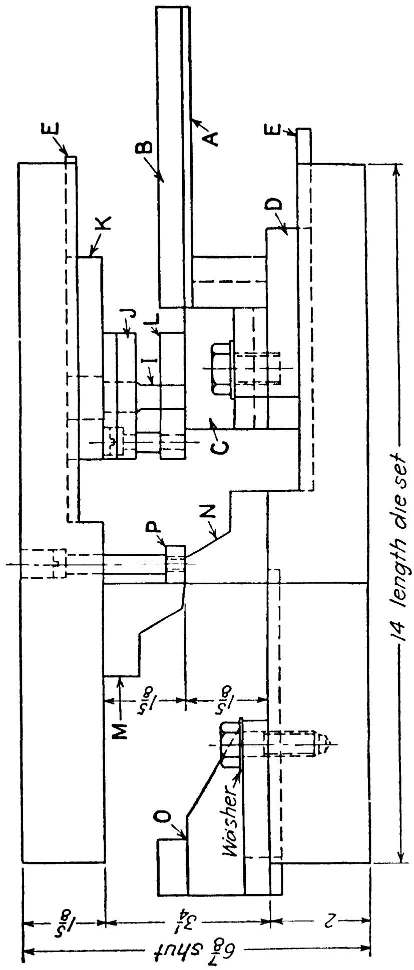
Shearing Across the Strip.—The shearing punch and die, *M* and *N* respectively, are rigidly attached on the punch holder and die shoe. Adjustments for these members are unnecessary because the width of the blank can easily be determined by adjusting the die blocks and altering the position of stop *O*, at the left of the cutting-off station.

A spring pad *P* holds down the strip while punch *M* descends and cuts off the blanks. The cutting edge of this punch is provided with a relieved shearing angle, not shown, which extends along its entire length. These cutting-off members are the same length as the width of the die set, which is 14 in., and will shear off blanks nearly to that length.

Adjustable Stop.—Stop *O* can be adjusted in lateral directions in the slot shown and is clamped with a cap screw. The stop is clamped at the same distance from the edge of cutting die *N* as from *N* to the centers of the square piercing holes in blocks *C*. This dimension is, of course, the width of the desired blanks and is the blanking center dis-


12
Washer
B
A
E
D
℄ Press and die
E
H
G
C
C
H
F
F
Cut off edge
O
14 width die set

PLAN



FRONT ELEVATION

FIG. 59.—Adjustable notching and cutting-off punch and die for producing many sizes of sheet metal box blanks.

tance. The blanking centers being variable, it was necessary to provide these adjustments.

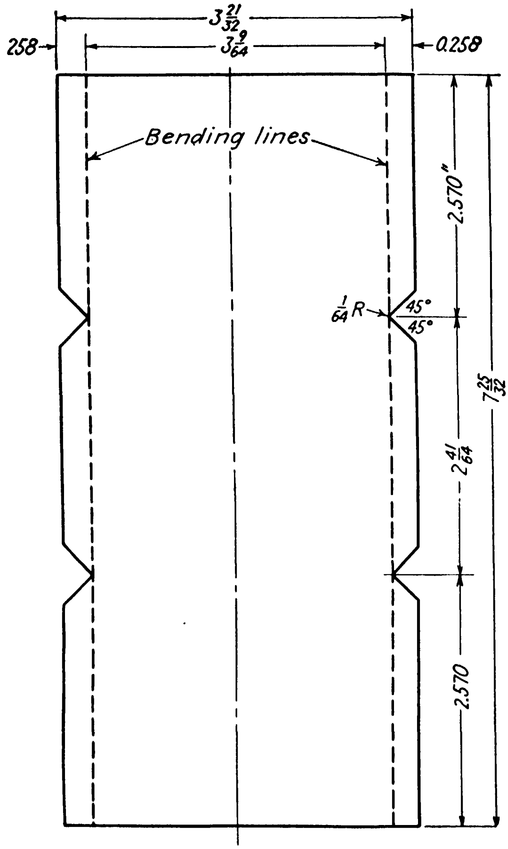


Fig. 60.—One of the many sizes of steel box blanks possible to produce in the adjustable die shown in the preceding sketch.

Blank Delivery.—The tool is used in a tilted press. After cutting off the blank, the punch continues to descend and tips the blank down against the angle in front of stop *O*, thus freeing it to slide from the die and fall behind the press.

CHAPTER IV

BENDING AND FORMING DIES

Nomenclature.—There are times when confusion arises regarding the difference in meaning between bending, forming, and drawing dies. The term "forming die" comes within the general meaning, but does not have a specific meaning. A "bending die" forms angles. A "forming die" bends curves. A "drawing die" forms shells or cups. But these simple definitions are too much abbreviated.

What Is a Bending Die?—A bending die changes the original plane of a blank to planes in other directions; it produces one or more angles either by bending projections on a blank or bending across its entire length or width.

What Is a Forming Die?—A forming die changes a blank into one or more varieties of shapes, or it may stretch, curl, twist, indent, fold, or upset any part or parts of a piece.

What Is a Drawing Die?—A drawing die forces a blank into a high state of plastic flow, causes it to "hug" the shape of the punch, and produces a shell, cup, pan, or whatever the punch contour. The part has a continuous wall with a constant thickness.

Corner Bends.—A bending or forming operation may produce angles anywhere up to 180 deg. and may require more than one die. The inside corner of the bend may be sharp, or it may have a certain radius. Usually the corner radius is made large enough to avoid undue weakening of the bend, to prevent either stretching or fracturing it when the material is of low ductility or the grain direction lies the wrong way.

"Spring-back."—It is usually necessary to make bends and forms greater than is actually required to compensate for spring-back in the finished piece. The exception is when using spring-pad forming dies, in which the punch "irons" the metal, as it descends outside the bend, which relieves the bending strains.

V-bending Dies.—Using a "V-block die" is the simplest way to bend sheet metals in a punch press. The resulting work is not very accurate, but it may serve its purpose well when a large number of parts are wanted in a hurry, and if the size restrictions are not too severe.

Figure 61 shows the die in its closed position. Angle A on the punch face is made *less* than its corresponding die angle to overcome spring-back in the finished work. The difference in the angles is determined by experiment in the toolroom. Spring-back varies

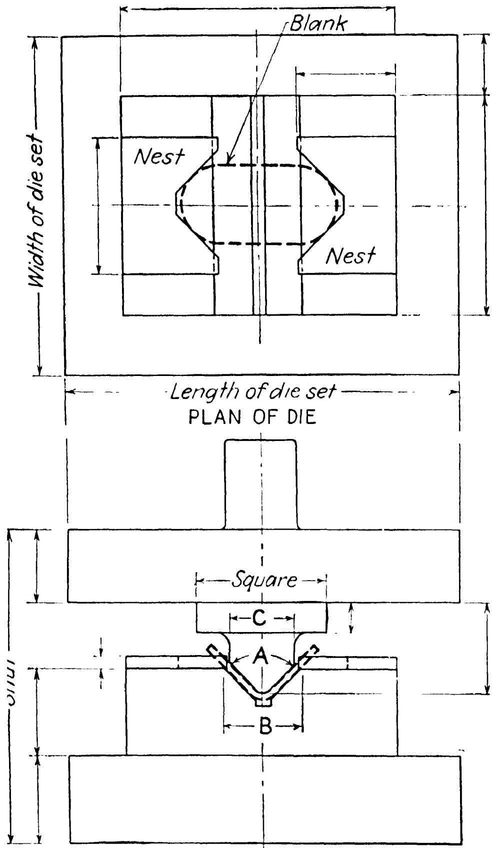


Fig. 61.

according to the thickness and temper of the work material. For bending "dead-soft" steel, angle A may be diminished about $\frac{1}{2}$ to 1 deg., for hard-rolled steel 4 to 5 deg., but for high-tempered spring brass, phosphor bronze, or tobin bronze sheet, it may be 12 to 15 deg.

Dimension B, which is the width of the V, should not be less than fifteen to twenty times the thickness of the work material; otherwise imperfect bends will be produced. Dimensions B and C must be

sufficient to ensure a definite "set" in the bend at the maximum descent of the press stroke.

Spring-pad Die for Side Bends.—Figure 62 represents a typical die design for side-bending operations in spring-pad dies. The work is positioned on the die by two positive pins that enter corresponding

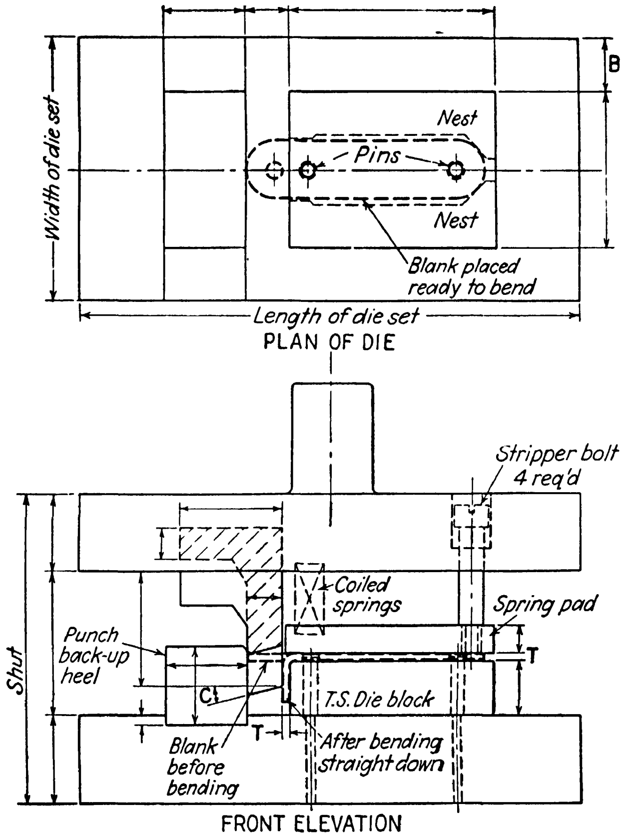


FIG. 62.—Side bend made in a common type of spring-pad bending die. Increasing angle C, on the face of bending punch, decreases the pressure required to make a bend.

holes in the blank. If there are no holes in the blank, a "nest" of plates can be arranged to locate the work, as indicated by the light dashed lines in the plan.

When the ram descends, the spring pad contacts the blank first, holding it flat on the die while the punch continues to descend and bends the angle straight down.

The light sectioned punch, in the front elevation, is shown in descent at the point where its tip end first contacts the blank. Here it will be observed that when angle C on the punch is increased, it mate-

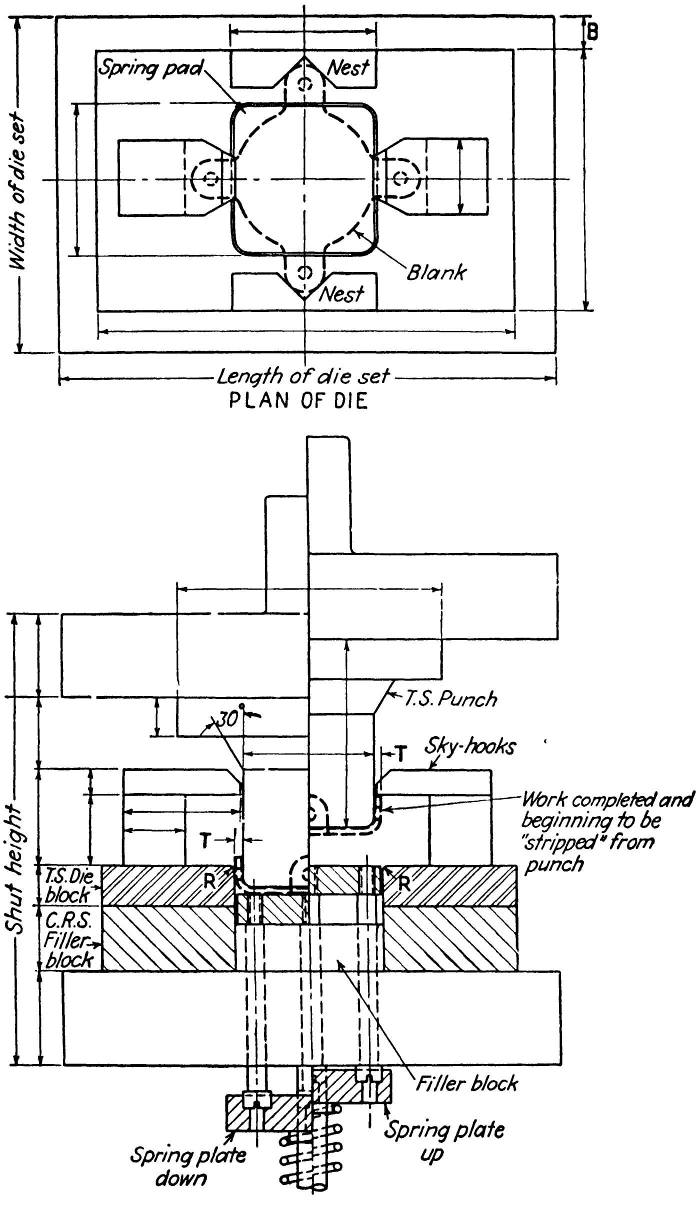


FIG. 63.—An enclosed type of spring-pad bending punch and die.

rially decreases the bending moment of the operation. The punch passes the bend deep enough to "iron" thoroughly the metal outside the bend. This action tends to eliminate spring-back in the finished work. A positively attached heel backs up the punch and prevents its deflection.

While this die is a small-operation tool, the same design can be expanded for bending larger work. However, very long bends of these types are usually performed in a press-brake machine.

Enclosed Spring-pad Bending Die.—This die is drawn in Fig. 63, which shows the left half of the tool shut, four ears on the work "thrown up," and corners "spanked" at the maximum down-stroke. The right half is shown in ascension. The completed work, adhering to the punch, has been carried up into contact with the "sky hooks" and is just ready to be "stripped" off as the punch continues up. The press being tilted back, the work slides away behind the machine.

The blank is positioned over the spring pad as shown in the plan view. It is located in two "V nests." The clearance between the exterior of the punch and the interior of the die is *T*, which is the thickness of the work material. The punch, in descent, depresses the pad and carries the blank and its ears down against radii *R*. As it continues to descend, the interior of the die "throws up" the ears on four sides of the punch. Radius *R* should not be less than thickness *T*. This die also "irons" the outside of the bends opposite the corners and reduces spring-back to a minimum.

DIES WITH EXPANSION PUNCHES FOR BENDING U-SHAPED FRAMES FROM CHANNEL STOCK

Collapsible Punches for Close Die Spaces.—When employing a punch press for bending deep or long U-shaped frames from channel stock, a bending punch is used that expands and collapses automatically. This feature is necessary because the die space and crank stroke of the average punch press are insufficient to permit the work to be stripped from the punch by conventional methods after it has been bent to a U shape, as indicated by the dot-and-dash lines at *A*, Fig. 64.

The punch shown in Fig. 64 will collapse to a width *B*, Fig. 65, clearing the minimum space *C* between the edges of the channel and thus freeing the work from the punch. With the punch collapsed, as shown in Fig. 65, the completed work *A* can be withdrawn horizontally from the die. There are several designs of collapsible bending punches, the choice usually depending upon the width of the channel work.

Description and Operation.—The first die operation performed in producing the frame shown at A, Fig. 64, is to notch the flat sheet material and bend up the edges to give the channel section the shape required. This operation is not illustrated, Figs. 64 and 65 showing

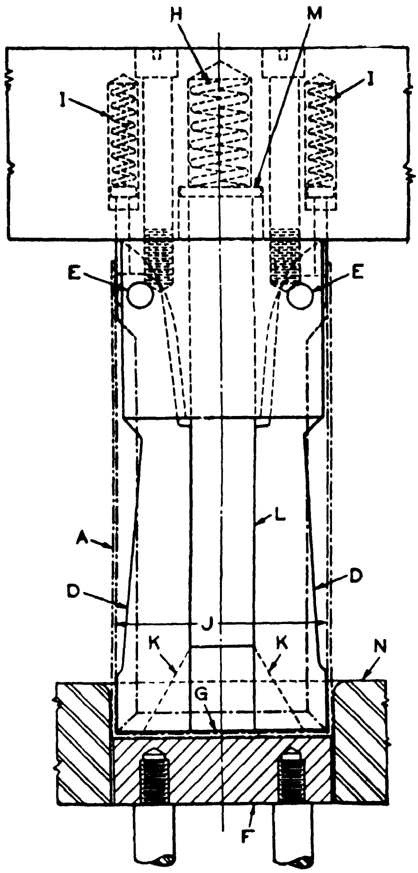


FIG. 64.—Die with an expansion punch D for bending the deep U-shaped frame A. The work material is 0.0375-in.-gage cold-rolled steel.

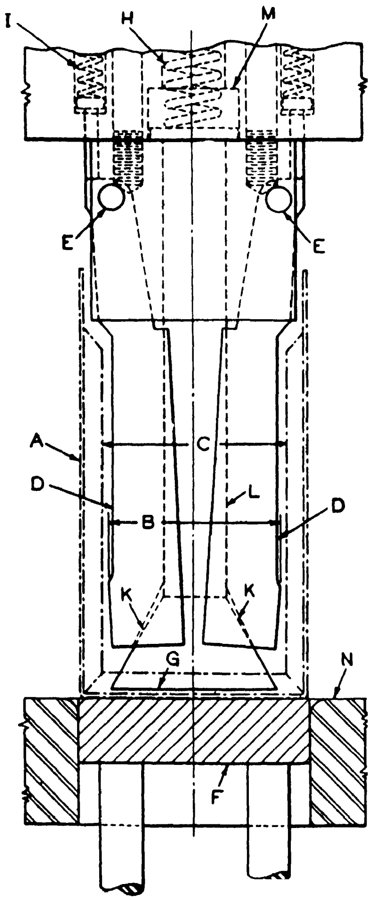


FIG. 65.—Die shown in the preceding sketch with its punch collapsed to permit removal of the completed U-shaped frame A.

only the die with the collapsible punch employed for the second operation.

The two collapsible side arms D are pivoted on fulcrum pins E. The channel to be bent is located on spring pad F so that the descending punch first comes in contact with the work on surface G. As the punch continues downward, springs H and I are compressed and the punch is

expanded to its full width J by the cam or angular surfaces at K when rod L "banks" at M. Upon further downward movement of the punch, spring pad F is depressed and the channel is bent to a U shape within die block N.

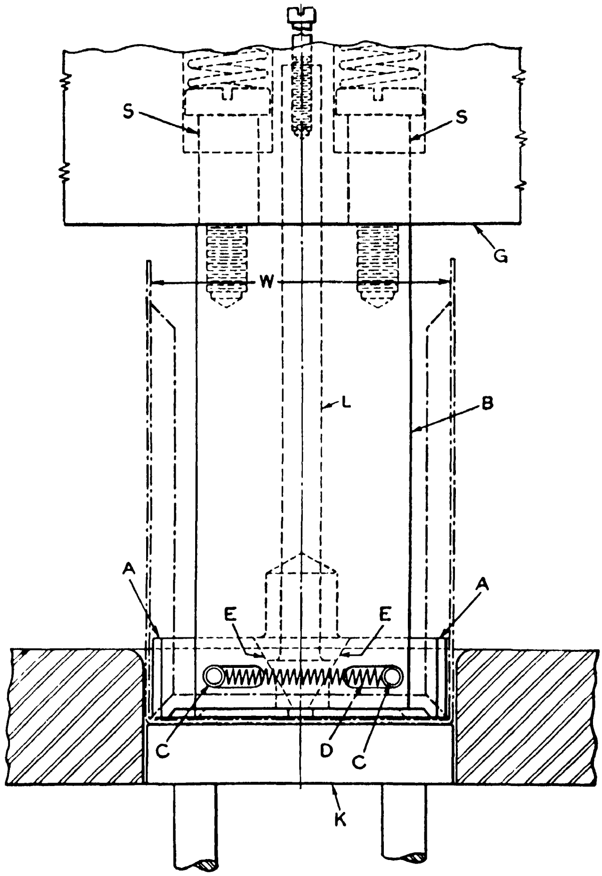


FIG. 66.—Die of simpler design for a bending operation similar to the one performed by the die shown in Figs. 64 and 65.

When the punch ascends, it is followed upward by the work until the top of pad F is flush with the surface of die N, as shown in Fig. 65. The punch, continuing to ascend, allows spring H to force rod L and its cam surfaces K downward, thus causing pivoted arms D to collapse and leave the finished work standing free on the pad, ready for removal, as shown at A, Fig. 65.

A Simple Collapsible Punch.—Another punch, of simpler design, used for a similar bending job is shown in Fig. 66. Bending punches A of this die are arranged to slide in a slot cut across the bottom of punch

body *B*. This design can be used only when the width *W* between the bent sides of the channel is wide enough to permit using a slot of sufficient length to maintain accurate alignment of the bending punches when they are expanded to full width.

Punches *A* are provided with pins *C* that slide in transverse slots cut through the sides of punch body *B*. Two tension springs *D* hold punches *A* in contact with angular or cam surfaces *E*. Punches *A* are moved inward and outward by cam surfaces *E* on rod *L* and the springs *D* in accordance with the movements of the press ram.

The two large shouldered screws *S* are sliding fits in punch holder *G* and allow punch body *B* to move vertically. Compression springs over the screw heads cause body *B* to slide downward on rod *L* when the ram ascends. This action causes punches *A* to recede and to leave the finished work standing on the pad, ready for removal either by the operator or automatically by means of compressed air. The springs used for collapsing the punches must always have a weaker action than those used under pads *F* and *K*, Figs. 65 and 66.

DEVELOPING THE LENGTHS OF FORMED WORK

The Three Cases for Bends.—Using the given dimensions of a formed piece of work, all the arcs, right-angled bends, and angles must

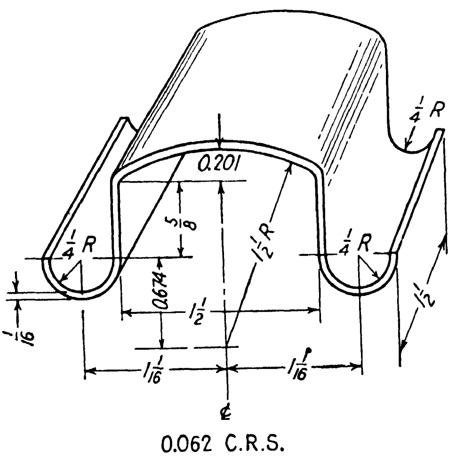


FIG. 67.—A sheet steel piece, one of which is completed at each press stroke.

be straightened out into a flat blank layout before beginning the die design. There are three cases of bends to be considered. (1) Length of arcs for 90-deg. bends across the grain in V dies. (2) Length of arcs for 90-deg. bends across the grain in spring-pad dies. (3) Length of arcs when the bending radius is more than twice the thickness of the sheet. In case 1, the neutral bending line is at one-third of the material

thickness from inside of the bend. In case 2, it is at one-fifth of the material thickness, and for case 3, it is at one-half of the material thickness. When R is the radius and T the material thickness, the length of a 90-deg. bend for case 1 is $(T/3 + R) \times 1.5708$; for case 2, $(T/5 + R) \times 1.5708$, and for case 3, $(T/2 + R) \times 1.5708$. All the lengths of bends less than 90-deg. angles are their proportional part of a 90-deg. bend. (See tables for bends on pages 466 and 467.)

Finding Developed Lengths.—In Fig. 67 is a formed piece of work that belongs under case 3. The length of the blank is determined as follows. Make a layout showing the neutral bending line, a sketch similar to Fig. 68, and dimension it according to case 3. The mathematics involved here can readily be applied by any good high-school student. It is observed, of course, that dimension 0.674 in. is necessarily a constant in both Figs. 67 and 68. This being so, dimension 0.643 in. is found by subtracting the sum of 0.674 in. plus the arc height 0.214 in. from $1\frac{17}{32}$ in. The formula for finding the height of any segmental circular arc is $H = R - \sqrt{R^2 - B^2}$, in which H is the height of arc, B half the length of its subtending chord, and R the given radius of the arc.

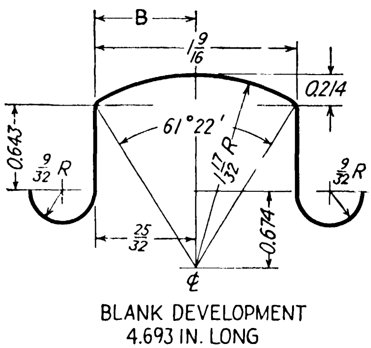
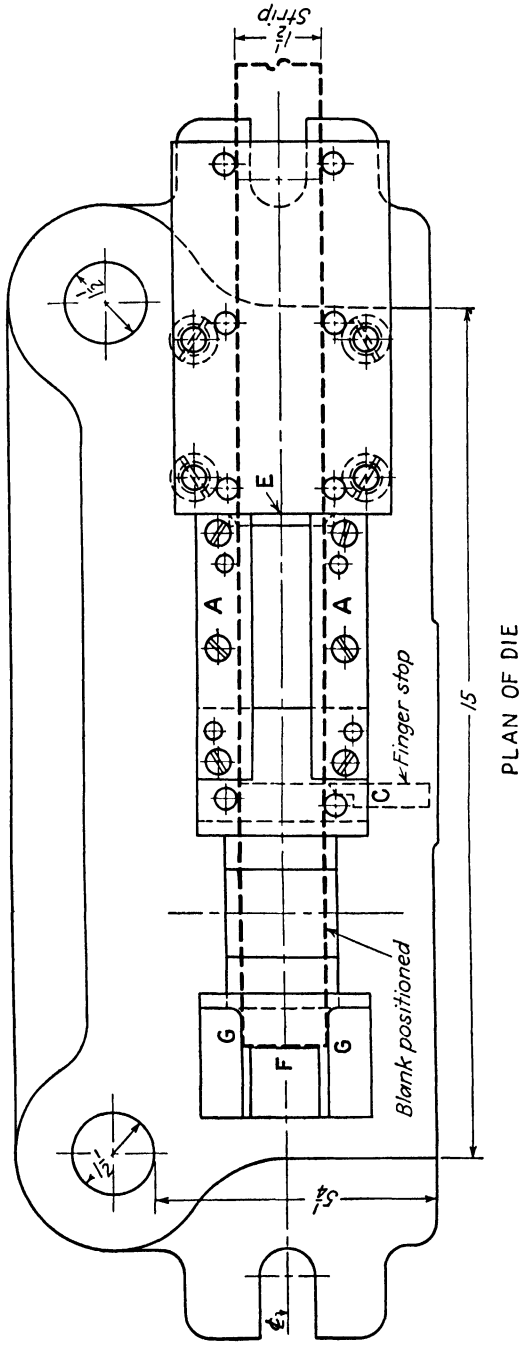


FIG. 68.—The neutral bending line in the preceding figure dimensioned along the center line of its gage thickness.

To determine the length of arc, the angle it subtends must be found. This is simple trigonometry, in which B/R is the sine of half the angle wanted. By consulting a table* giving the lengths of arcs in a circle whose radius is 1 or unity, for 61 deg. and 22 min., and multiplying this length by $1\frac{17}{32}R$, we have 1.640 in. The total developed length for this blank is then 1.640 in. plus $2 \times$ (0.643 in.) plus the circumference of a circle whose diameter is $\frac{9}{16}$ in., or a total length of 4.693 in. There is a negligible difference at the two sharp corners that can be ignored.

Designing the Die.—The piece under discussion, Fig. 67, is to be completed, one at each stroke of the press, and in a low-priced die. This order has several troublesome restrictions, and, if studied without recourse to the die layout in Fig. 69, it is found to be quite a difficult problem. Simple as this job at first appears, with its several appar-

* These tables are found in books of seven-place logarithms such as "Vega" and similar publications.


Strip
E
A
A
Finger stop
C
15
Blank positioned
G
F
G
PLAN OF DIE

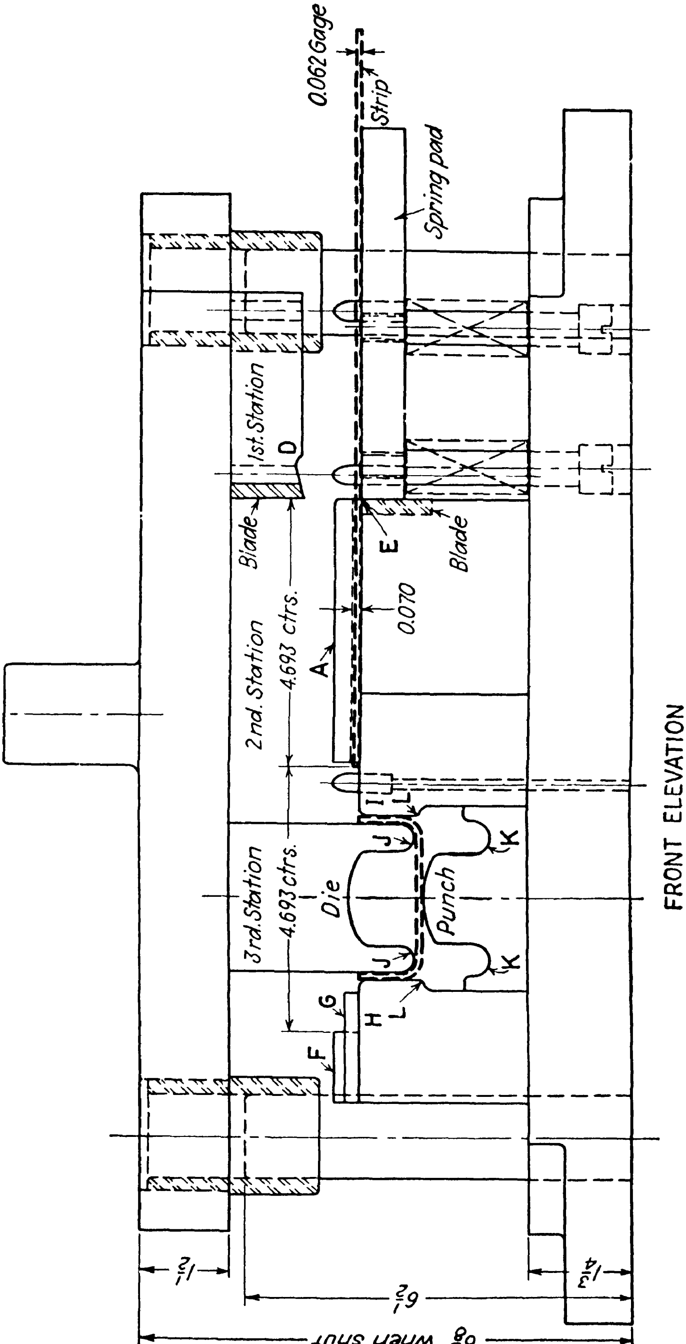


FIG. 69.—This die cuts off a blank, draws two curled ends down into the die, thus forming the body of the piece, and then "spanks" the work to size at the extreme downstroke of the ram.

ently easy solutions for a die design, it is not so easy. It would be a difficult job to do even in two or more operations, given the cheap die restrictions.

The die illustrated has two outstanding features worthy of our attention: (1) The blank is severed from the strip at the station previous to forming; this avoids a bad condition in cutting off too close to the forming die. The blank is cut just before the maximum downstroke occurs. This could not be done at the next station ahead, because the blank must be cut off before forming can begin. (2) "Slip curling" or drawing the two ¼-in. radial semicircles down into the die where they are "spanked" to size at the completion of the downstroke.

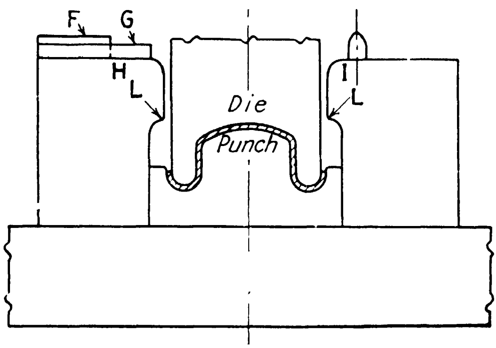


FIG. 70.—Shut position of the forming punch and die.

Operation of the Die.—The strip and work are the same width, 1½ in.; the strip is guided over a spring pad and between gage pins, and then under the retaining channels *A*, until its forward end registers against the depressed finger stop *C*. When the ram descends, punch *D* cuts off one blank length at *E*. The blank is then pushed forward by the next advance of the strip, until it registers against stop *F* and within guide blocks *G*. The strip clearance under channels *A* is only 0.008 in., and this holds the blank in approximately the same horizontal plane as the top of forming block *H*, so that in passing the blank over the forming die it cannot fall into the die opening.

On the next descent of the ram, the die "throws up" the blank ends, and, continuing to descend, the die causes the ends to enter between blocks *H* and *I*, while the center of the blank begins contact with the forming arc across the top of the punch, as shown in the front elevation. At this stage, the operation is almost half completed. From here on, the die begins to "slip-draw" the blank ends down between blocks *H* and *I*, around *J*, and over the punch body, while the curled ends enter into the receptacles *K*. At maximum descent, the punch and die

squeezes the work between them and completes the piece, as seen in Fig. 70, the shut position of the die.

Allowances for Spring-back in the Work.—The sizes of radii J and K must be experimentally determined by the toolmaker. These radii must be smaller than specified in the dimensioned piece. The reason for this is the inevitable spring-back of the steel material when drawn into the curls. On ascent of the ram, the work clings in the die, because of the spring-back, and the upper edges of the curls contact points L, which "strips" the piece from the die.

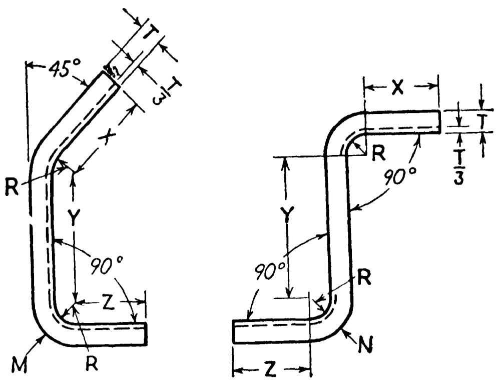


FIG. 71.—Illustrating the simple methods employed for calculating the developed lengths of formed blanks.

Inserted Cutting-off Blades.—Notice at cut-off point E, and in punch D, that separate cutting blades are inserted. This is an advantage when desirable to alter the cut length of the blank. It is done by simply changing the thicknesses of these blades.

Calculating Blank Lengths.—Figure 71 shows the principle used in applying the formulas given for developing the lengths of formed work.

At M the developed length is

$$\left(\frac{T}{3} + R\right) \times 1.5708 + \frac{1}{2}\left(\frac{T}{3} + R\right) \times 1.5708 + X + Y + Z$$

At N, the length is

$$2\left(\frac{T}{3} + R\right) \times 1.5708 + X + Y + Z.$$

BLANKING, FORMING, AND COMPUTING BENDS

Description of the Work—The part shown in Fig. 72 is used in conjunction with a ball stud for the adjustment of a deflector plate on

an automobile heater. There are 12 bends in this part, and allowances must be made for all of them if the work is to come out of the dies to the correct dimensions.

Allowance for Bends.—In making the blank layout shown in Fig. 72, use was made of the common assumption that the neutral bending line is one-third the distance from the inside of the completed bend.

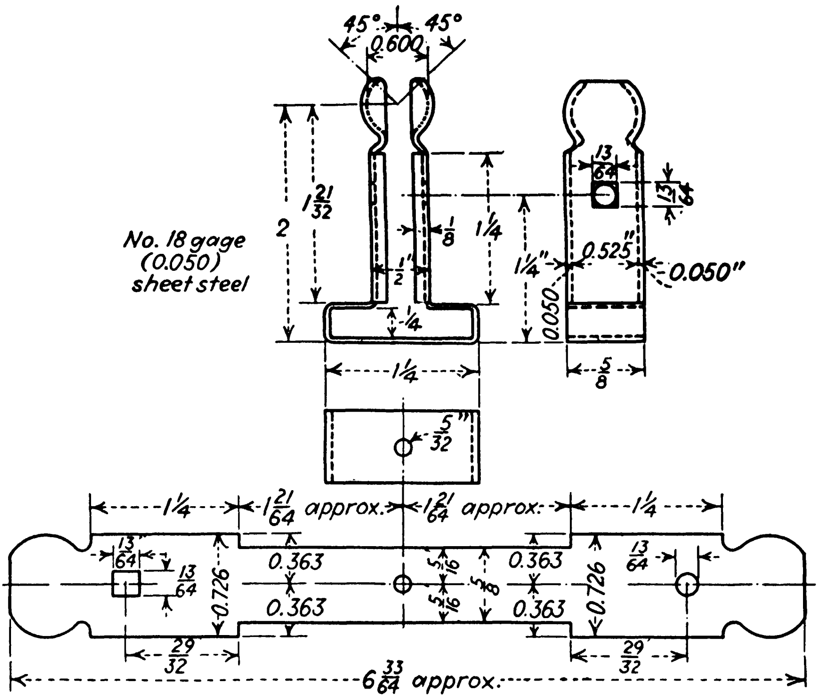


FIG. 72.—At the top is the finished part that is to be riveted on the heat-deflector shield. Below is the blank development, all bending allowances having been included.

The bends are sharp. From a table of bend allowances it was found that 0.026 in. must be added to the inside dimension of each 90-deg. bend and half that amount for each 45-deg. bend in order to get the true developed length and width of the blank. The ball cups, being less than hemispheres, did not require great accuracy. Therefore, they were made to the developed width of the body. Tables for bending allowances are given on pages 466 and 467.

The Scrap Strip.—The next step was to determine the scrap allowance, the strip width, and the blanking centers. The width of the strip was taken at $6\frac{3}{4}$ in. While this width allowed $\frac{1}{8}$-in. neck of metal on each side of the strip after blanking, the allowance was deemed a

measure of safety in case it became necessary to increase the length of the blank.

The Blanking Die.—In Fig. 73 is a plan of the perforating and blanking die. The strip is run through the die under a positive-type channel stripper plate attached over the die block.

First Forming Die.—The first forming and drawing die is shown in Fig. 74 in closed position and with the formed work between the

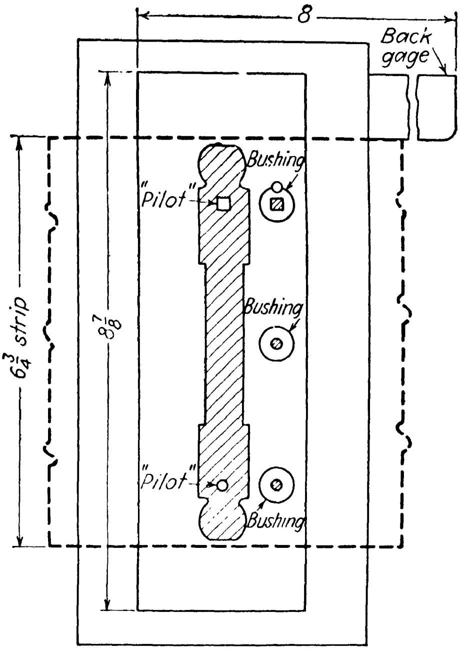


FIG. 73.—A two-station piercing and blanking die ensures accurate work when two locating pilots are used in the punch face, which is shown section-lined in the die opening.

punches and dies. Two blocks *A* work against springs in the die shoe, while the corresponding blocks *B* are rigidly attached to the punch holder. Blocks *C*, which carry the dies for forming the cups, are rigidly attached to the die shoe, and the corresponding forming punches are attached to the punch holder.

Block *D* is a spring pad and is a sliding fit inside of the blocks *F*. It works against the forming punch *H*, which is actuated by a spring in the punch stem that is stronger than that under spring pad *D*. The blank is laid between four side-locating pins in blocks *F*, and its endwise location is obtained by placing the $\frac{5}{32}$-in. central hole over a pin in spring pad *D*. When the ram descends, the blank is first con-

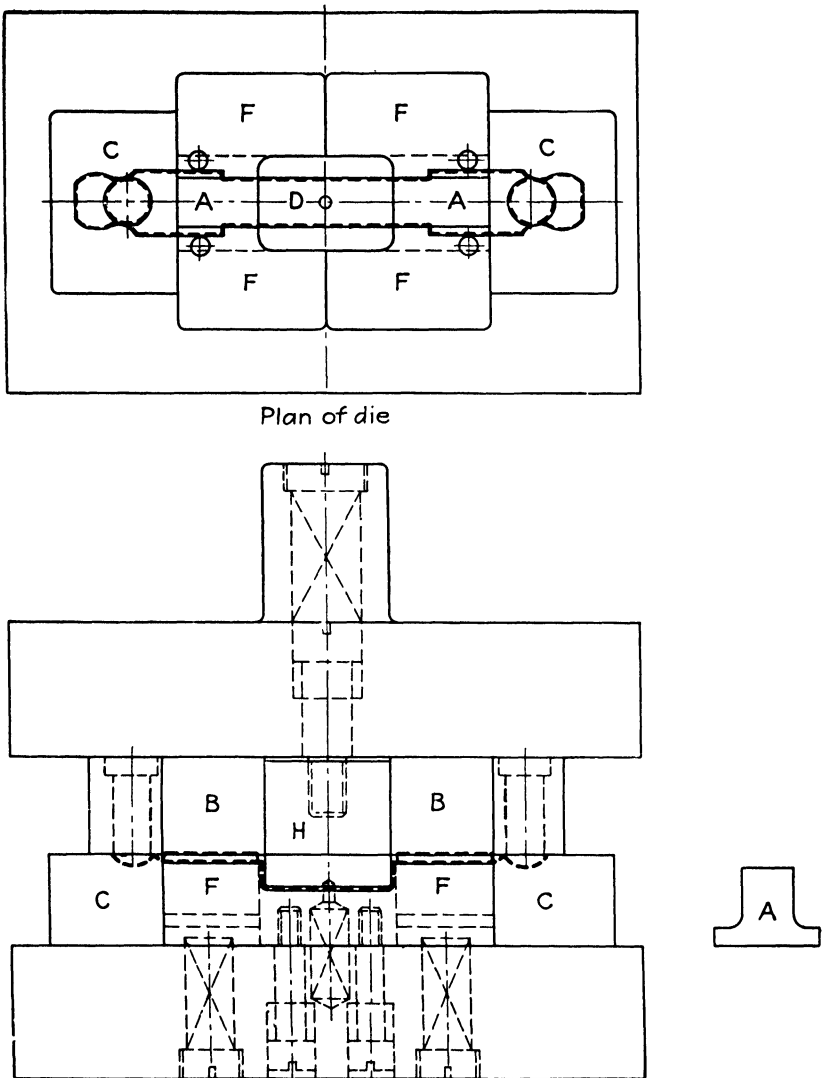


FIG. 74.—In the first forming die the blank is positioned sidewise between four gage pins and endwise by a gage pin in spring-pad shedder *D* within the die. The pin in the shedder engages in the center hole of the blank.

tacted by the punch *H* against the spring pad and draws and forms the work between blocks *A*. Thus far the length of the blank has been diminished on both ends, and the two blank ends for the cups have been brought into position under the forming punches.

As the ram continues its descent, the four sides ($\frac{1}{8} \times 1\frac{1}{4}$ in.) are formed between blocks *F* and *A*, but when spring pad *D* and blocks *A* finally register against the die shoe, the cups and the sides have been

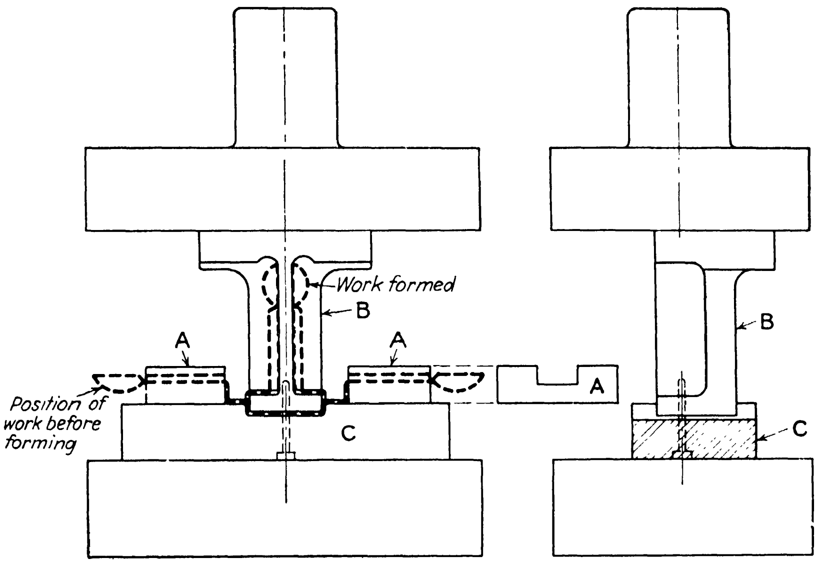


FIG. 75.—In the final bending operation the work is again located endwise by a gage pin through the center hole. When punch *B* descends, the long ends are bent upward, bringing the ball cups into correct position.

finished and the work in this operation has been completed. As the ram ascends, the spring pads and the blocks follow it up until stopped flush with the die, when the punch begins to leave the work. The three spring pads then eject the work from the die, and an air jet causes the work to rise and clear the pilot pin and fall out at the back of the press.

Second Forming Die.—The tools for the last operation are shown in Fig. 75 in the closed position. This operation consists in folding up the long sides of the work to its finished height of 2 in. The work is laid in channel blocks *A* for side location, and its central hole is again placed over a $\frac{5}{32}$-in. pilot pin. When the ram descends, punch *B* contacts the work on its face in which a clearance hole is provided for the pilot pin. As the ram continues to descend, the blank is forced between the sides of the forming channel *C*, and since only the thick-

ness of the material is allowed on the sides for clearance between the forming punch and the die, the long sides must be forced up into completion.

No springs are used in the tool for the last operation. The forming blocks and the punch are rigidly attached to the die shoe and the punch holder respectively. The forming punch is relieved at its front, but not deep enough to impair its strength, and to a sufficient height to permit the long sides of the work to fold toward each other and "flat" against the punch blade without interference. The finished work is removed by the operator with a hand hook. The production did not warrant the extra expense of an automatic ejector. However, such a device could be attached. It could be operated either by a hand lever or by an air piston actuated by a valve operated by the ram ascent.

If the output is large enough, these three dies with their separate operations can be redesigned into a single progressive die that will produce one finished part at each stroke of the press.

CHAPTER V

"CUT-AND-CARRY" PROGRESSIVE DIES

Cutting and Bending Four Angles Simultaneously

Discussion of the Principle Involved.—During the First World War, someone discovered that, instead of cutting light metal blanks clear through the die and losing them for further operations in the same tool, the blank outline can be trimmed from the strip on the surface of the die block by using notching punches placed at either or both sides of the strip.

A neck of metal can be left to connect the blanks for the purpose of passing them along with the strip into subsequent stations for additional operations. In this way it is possible to perforate holes, cut the blank outline, shallow-draw, emboss, form, or what not, and finally to cut off the finished piece intact. If drawing or embossing distorts the strip, these operations are performed first, and notching, trimming, and piercing follow.

All these operations are performed on the surfaces of the die blocks, and the scrap is not only eliminated through the die openings, but is also segregated from the finished pieces, which fall through a separate clearance hole at the left of the die or, after being cut off, are blown into a chute beside the press. These dies are very economical of material; generally the only scrap is the slugs from the pierced holes and side trimmings around the blank.

Work Completed in One Press Stroke Is Highest Tool Efficiency.—Cut-and-carry dies with five or more stations are sometimes rather complicated. In building them, it is advisable to make experimental stations for trying out one or more of the proposed operations in order to determine the tooling difficulties. Especially is this necessary for operations that have no precedent. These dies require experienced designing and toolmaking, and some of them are expensive to build, but fortunately the die soon pays for itself when put into continuous production.

Production Speed.—For light parts, such as radio and telephone connectors, tinned solder lugs, and belt links for machine guns, the blanks are trimmed to size and progressively embossed, drawn, pierced, formed, and cut off, one piece per press stroke, at the rate

of 140 pieces per minute. For simpler work, some of the modern high-speed presses can produce up to 1,000 or more pieces per minute, on a conservative basis. With a single Dieing machine and properly designed tools, one operator is able to produce more stampings in the same time than a number of operators who use conventional dies to produce the same piece in the old way. The Multislide and similar metal-fabricating machines are intended to use these types of progressive dies.

Single-row Designs Are Best.—Cut-and-carry dies are usually designed for single rows of work, but some simple parts can be run in double rows. This is often the case for right- and left-handed parts. It is not practical to attempt running more than two rows, because

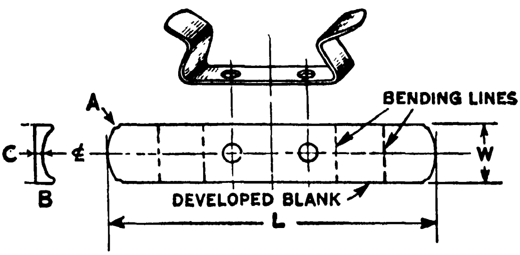


FIG. 76.—A "dove-tail-shaped" snap spring and its blank development. This part requires a high-speed progressive die for its production.

the die would be so complicated that the time lost trying to locate troubles, and the repair costs, would be excessive.

Quite large pieces can be successfully run in these dies—steel parts of 0.0625 in. gage, 5 or 6 in. long by 3 or 4 in. wide, and up to 3 in. high. The size of the parts to be made depends, of course, on the capacities of the presses available, their size, stroke, and die spaces.

A Typical Piece for Cut-and-carry Production.—The flat spring clip, of 0.0375-in. hard-rolled steel, shown in Fig. 76, represents the work for which the progressive die in Fig. 78 is designed. Below the piece in Fig. 76, is the blank development, or length L. In developing blanks, when the bending radii are less than twice the material thickness, the developed length is computed along a neutral bending line situated at one-third the material thickness from the inside surface of the bends. In this case, however, one-half the material thickness is used because the bending radii are greater than two thicknesses of the metal. Tables for bending allowances are given on pages 466 and 467.

The "nipped" corners at A are provided to facilitate shearing the blanks apart. If a sharp angle is used here, not only will the cutting

members wear rapidly at the sharp point, but the sheared-off pieces will appear imperfect at the ends if the shearing cut fails to coincide exactly with the angle. It is nearly always necessary to include this feature, or variations of it, to improve the appearance of the work at its point of severance.

Pounds of Stock Required per 1,000 Blanks.—For square-end blanks, the width of the material strip is length *L*, Fig. 76, but, as explained in a previous chapter, in cutting rounded ends or V shapes from the strip edges the cut slugs are likely to follow up with the punch and then be scattered over the die and work. This being so, a wider strip than length *L* is adopted so that in trimming the rounded ends the slugs will have parallel sides that cause them to cling in the die, as shown at *B*. The width of the strip is then *L* plus 2*C*. The area of one blank, in square inches, is the width of strip times *W*. The pounds of stock required per 1,000 blanks is the area of one blank, times the pounds weight of the material per square foot, times 7.3, which is a constant. This rule includes 5 per cent for waste ends of strips and misformed pieces.

Details of the Die.—Figures 77 and 78 set forth the order of die operations for finishing one completed piece of the clip (Fig. 76) per press stroke. The width of the material strip is *L* plus 2*C*. The sequence of operations is: (1) Trim ends and pierce. (2) Split blanks partially and form two opposite angles. (3) "Pilot" and form down angles U-shape. (4) "Pilot" and form "dovetail" with side cams. (5) Cut off the finished piece and push it through the die. Alternate stations are idle. The idle station provides metal between die openings and edges, gives better "piloting" and forming conditions, and adds to the rigidity of the tool. The piercing and pilot holes are all "bushed" for a possible change in the size of the holes, or for correcting distortion of the hole centers after hardening.

In station 4, the forming angles on the slides are made more acute than those of the work to compensate for spring-back in forming the work. The forming angles are a matter for experiment and are therefore determined in the toolroom. In Fig. 77 are three schematic views that show the end elevations of the first four die stations. It is always best to pierce holes in station 1 and then "pilot" from them in the following station. This feature aligns the strip and work in the die during its first stages and thus ensures correct progressive alignment of the work in the stations ahead. In Fig. 78, notice that the trimming punches in station 1 are provided with "back-up" heels that enter the dies before the actual cutting begins. The heels guide the punches and prevent nicked cutting edges.

This die is composed of four independent sections to facilitate grinding. After the surfaces of the cutting dies are ground, a similar amount is ground from the bottoms of the forming sections in order to align the die surfaces. If the forming sections become too low from repeated grindings, all the sections can be "shimmed up" with all the die surfaces in the same plane.

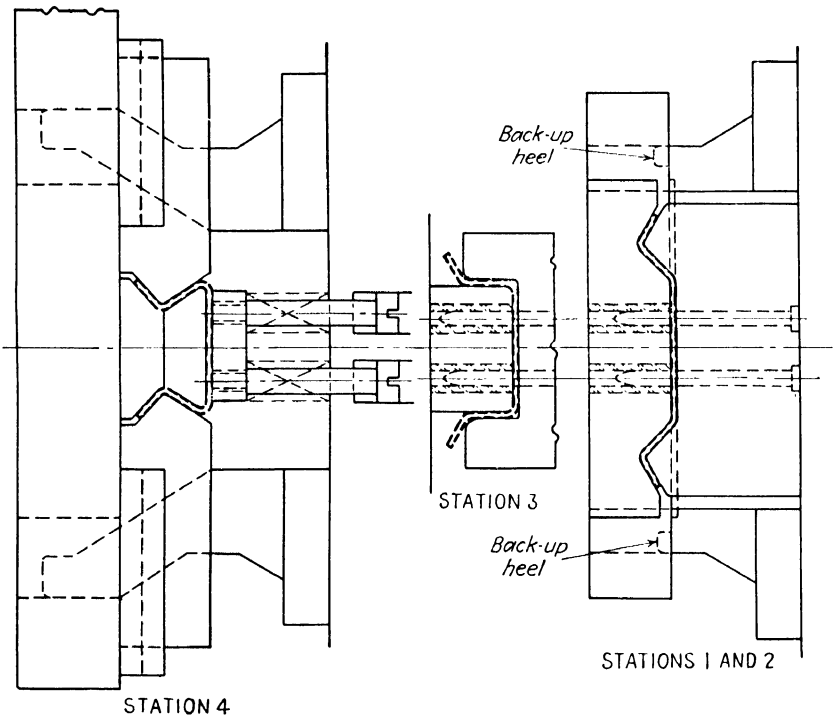


FIG. 77.—Three views of punches and dies, showing consecutive operations, which are end elevations taken from the left end of the die plan shown in Fig. 78.

Cut-and-carry for Heavy Work.—Failures in using these types of dies are sometimes met when attempting to run large steel work that exceeds about 0.0625 in. gage. Cut-and-carry operations in producing heavy pieces cannot be hurried; more time is required to fabricate them than for light-gage stock. If heavy blanks become distorted, or the strip runs out of line, they cannot be "spanked" straight or aligned with registering pilots so easily as flexible nonferrous strips. For heavy work, it is best to run only two or three operations progressively and possibly to include one forming operation and then finish the remaining forming operations in separate dies.

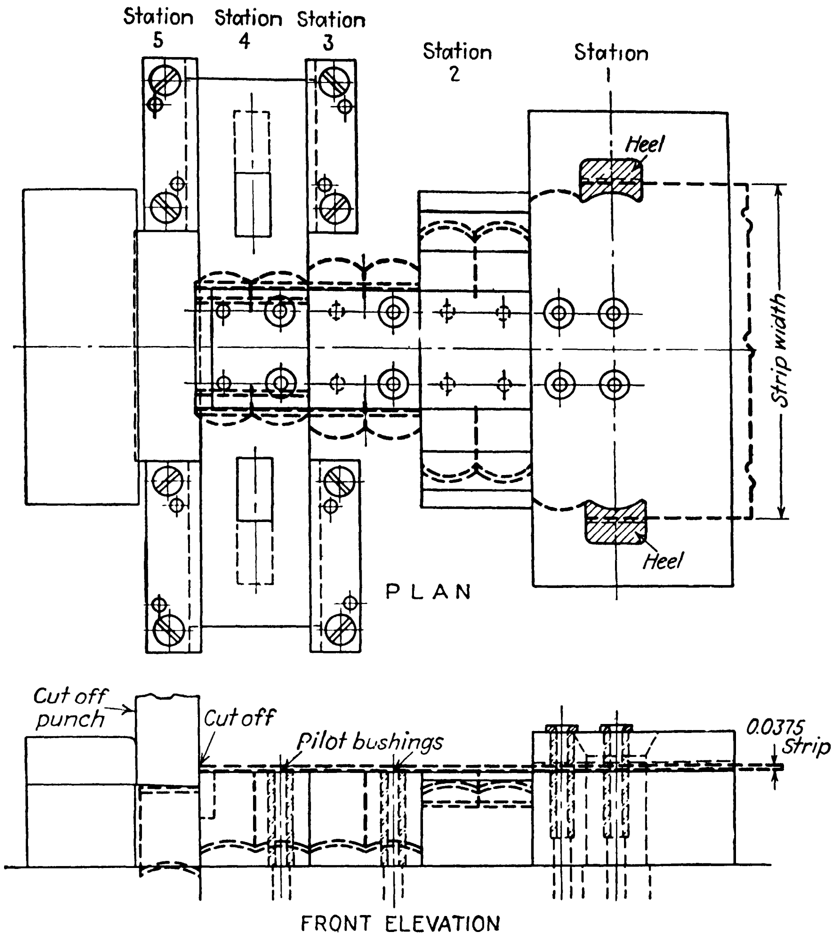


FIG. 78.—Plan and front elevation of a progressive die for quantity production of the snap spring shown in Fig. 76.

ONE PRESS STROKE COMPLETES THIS SMALL BRACKET

The Design of a High-production Press Tool for Progressively Piercing, Notching, Forming (Two Operations), and Severing the Piece from the Strip

Specifications.—The specifications for the part to be blanked and formed are shown in Fig. 79. In Fig. 80 are the scrap-strip design, including the shape after each operation, and important dimensions. For the blank development, the neutral bending line lies one-third within the strip thickness from inside the bends. For metal 0.025 in.

thick this distance is 0.008 in. or 0.008 in. radius for sharp corner bends, and 3.1416/4 × 0.016 in. = 0.013 in. Hence 0.013 in. is added to the sum of the inside finished dimensions for each 90-deg. bend. The strip width is the same as the developed length of the blank, or $^{29}/_{64}$ + 2(0.104) + 2(0.013) in. = $1^{1}/_{16}$ in.

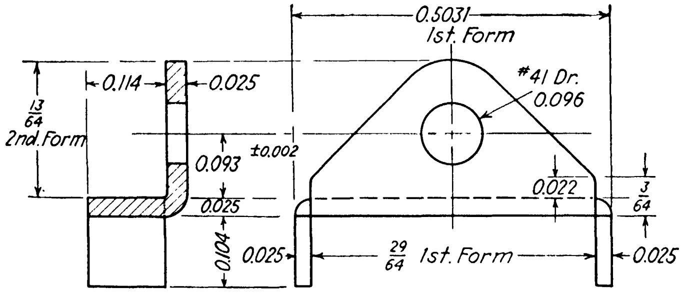


FIG. 79.—Specifications for the piece part called a "yoke," to be pierced, blanked, and formed progressively.

The Die.—Figure 81 shows the front elevation of the press tool and the plan view of the die without the stripper plate. The material strip is fed from right to left. Stripper plate *A* is the positive-channel type. It is attached on die block *B* with screws and dowel pins. The guiding width in the stripper-plate channel is made 0.004 in. wider than the maximum width of the strip. This precaution allows the

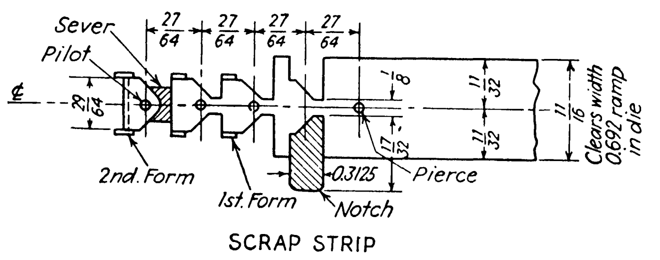
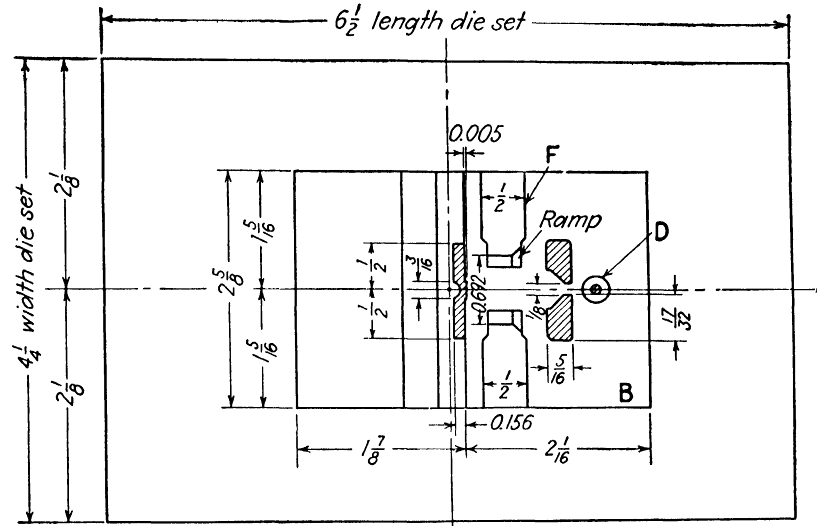


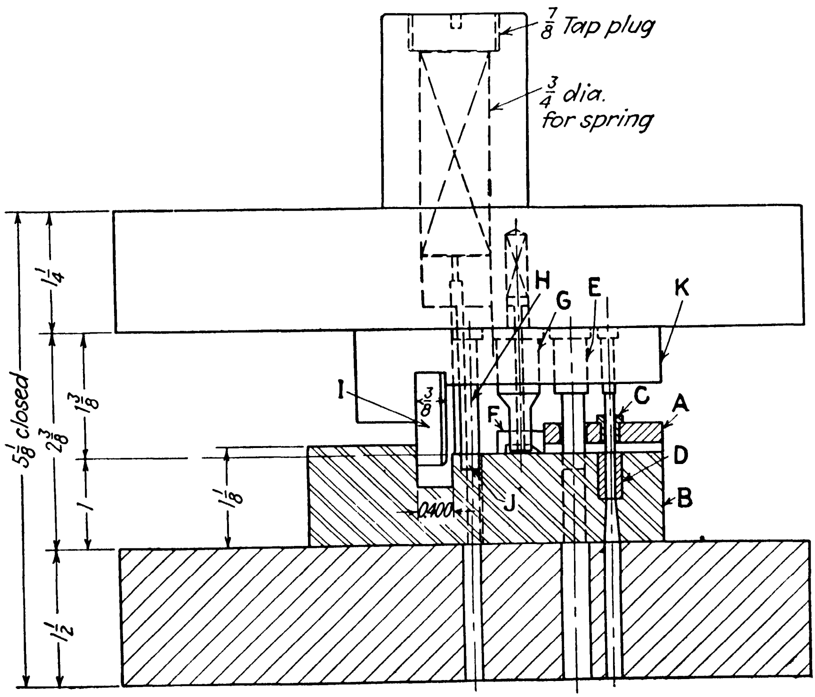
FIG. 80.—Scrap-strip design showing sequence of work shapes after each operation at the die stations.

strip to pass freely through the stripper channel, practically centralized in width over the die openings.

Piercing.—At station 1, where one hole is pierced, are members *C* and *D*. Member *C* is a commercial shouldered bushing pressed into a hole in the stripper plate, and when the ram descends it guides the piercing punch through the strip, pushing the blanked slug into die bushing *D*. The hole in the die bushing is tapered ¼ deg., enlarging



PLAN OF DIE



FRONT ELEVATION OF THE PRESS TOOL

FIG. 81.—A progressive die in which the yoke sketched in Fig. 79 is fabricated from strip stock.

toward the bottom, and, as the slugs accumulate, the punch in descent finally pushes them completely out through a clearance hole in the die shoe.

Notching.—After advancing the strip $27/64$ in. (the predetermined blanking centers), the work enters station 2, where both edges of the strip are notched to correspond with the blank outline shown in the scrap design. This operation is plainly shown in the plan view of the die. The punches are separated $1/8$ in. and leave a neck of metal of that width connecting the blank and strip by which the blank is advanced forward with the strip into successive stations. The neck is severed in the last station in which the final forming operation is also done.

First Forming Operation.—At station 3 the first forming operation is performed. This consists in "throwing up" two ears on the work

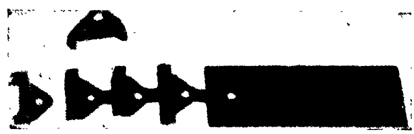


FIG. 81A.—Photograph of strip showing formation of part and two views of the finished yoke.

0.104 in. high. By advancing the work into this station, the strip is elevated $1/16$ in. by means of the short ramp shown in front of blocks F. The blanked ears to be formed now rest $1/16$ in. above the die face, and on the faces of the two outside forming blocks F. The distance between the outside shoulders on these blocks is also 0.004 in. wider than the strip width, and continues to guide the strip when it passes outside the stripper channel.

When the ram descends, it carries the forming punch G into flat contact with the blank. Since the punch has the same width as the required distance between the formed ears, and since the outside forming block edges are located symmetrically relative to the punch, with only the material thickness at each side between, as the punch forces the blank downward, the ears are necessarily formed up between the punch and blocks. The ear corners are "spanked square" by contacting the face of the die when forced by the maximum downstroke of the punch. Through the vertical center of forming punch G is a spring compression "push-off pin" which prevents the work from adhering to the punch when the ram ascends.

In station 4 no operations are performed. This idle station is necessary, however, to provide space on the punch holder for attaching two punches in station 5. For this reason, and to obtain more strength

of steel around the last die opening, idle stations are often employed in progressive dies for small parts.

Second Forming Operation.—When the work is advanced into station 5, the last station, and the ram descends, it carries down the "spring bumper punch" *H*, which contacts and firmly holds the blank against the die face for cutting off and second forming. The compression spring behind this punch lies in the punch-holder shank. This punch is guided by two shoulder screws, and its left side slides against the right side of final forming punch *I*, as shown. It also carries an aligning pilot pin which engages in the previously pierced hole in the blank. Between the two outer shoulders and on the right side of the spring punch, and around the pilot-pin boss, lies the cutting-off punch *J*. It has a radius of 3/32 in. around the boss, and a minimum cutting width of 0.092 in. for cutting out the connecting neck between the blanks.

In the next ram descent, two projecting lugs on opposite ends of the cutting-off punch align it by entering the 0.156-in. width of slot seen in the plan. Forming punch *I* contacts and bends the front end of the piece down a distance of 13/64 in. over the edge of the die block, while the pilot pin aligns, and the spring punch pressure continues to hold the blank firmly against the die face. When the ram ascends, the finished piece, having been cut from the strip, is blown behind the die by a jet of air. The press is tilted, and the finished pieces are blown under a sheet metal hood secured between the rear press frames, and then fall into a container.

Securing the Punches.—The punches are held by head flanges and aligned in punch plate *K*, as shown attached on the punch holder. The one exception is the last forming punch, which is secured by screws in a slot provided at the left end of the punch plate.

Feeding from the Coil and Reel.—For continuous runs, large coils of the strip material are purchased. The coil is centered on a stock reel which is an integral part of a floor stand on which the reel is mounted. It stands at the right of the press. The strip, in leaving the coil, first passes through a "hitch feed" attached at the right of the die and operated by a lug attached on the punch holder; the strip is thus advanced on exact blanking centers automatically. Each stroke of the press is used continuously, and the gross production is between 4,500 and 5,000 pieces per hour. The hitch feed is shown on Plate XVIII, page 425.

High-speed Piercing, Notching, and Cutting-off Die

Introduction.—Generally speaking, progressive dies are of two types, namely, those that cut the blank out of the strip, leaving a scrap

frame to be passed from the die, and those that do not. In the last-mentioned type, one of the blank dimensions must be equal to the width of strip, and such tools are often referred to as "no-scrap dies." A design showing this sort of progressive die is illustrated in Fig. 82.

The outstanding feature in progressive dies is that they perform several die operations at consecutive stations while passing the strip over them. The contour of the blank is trimmed by punches that work at the sides of the strip, as shown at *M* in the illustration. A connection of metal is left between the blanks for the purpose of passing them along with the strip. In this way, the blanks are fed into a rotation of stations ahead, for further operations. The consecutive order may be draw, pierce, notch, trim, form, and cut off. Pilots are made to engage in previously pierced holes to maintain the strip in alignment. As many as 10 stations may be employed. These dies can be used in ordinary gap-frame presses; they are used almost exclusively in the Multislide machines and Dieing presses and in several other high-speed metalworking machines.

"Cut-and-carry" dies are sometimes called "progressive" dies. This name indicates the manner in which the die operations are performed. The only scrap passing out of these dies is the perforated slugs, notching waste, and sometimes a narrow neck of metal when cutting off the piece at the last station. One of the blank dimensions being equal to the width of strip, it is necessary that the stock be purchased of a width specified within very close limits.

Progressive dies are employed to secure minimum width of strip and blanking centers, high-speed production, and continuous operation. The press can usually be run "wide open"; that is, the clutch pedal is held down continuously until the entire length of a strip has been passed through the die. These conditions suggest that the most economical length of strip, for uninterrupted production, would be the longest one possible to obtain. Therefore, in such die operations, the strip is usually fed to the die from a large coil of stock which is mounted on a reel. Feeding rolls, mounted between the press and reel, unwind the strip from the coil as needed. An oiling pad is placed over the strip between the rolls and the die, which provides sufficient lubrication on the strip before it enters the press tool.

The workpieces consist of small springs, clips, brackets, hinges, terminals, or connector lugs of light-gage materials. These products are used almost exclusively in the radio and electrical industries. Quite frequently the strip is "tinned stock." Strips may be purchased tinned on either one or both sides. Tinned strips offer no impediment to the operation of dies; their use really improves the fabrication of

some metals, especially where drawing operations are involved. Tinning facilitates drawing operations.

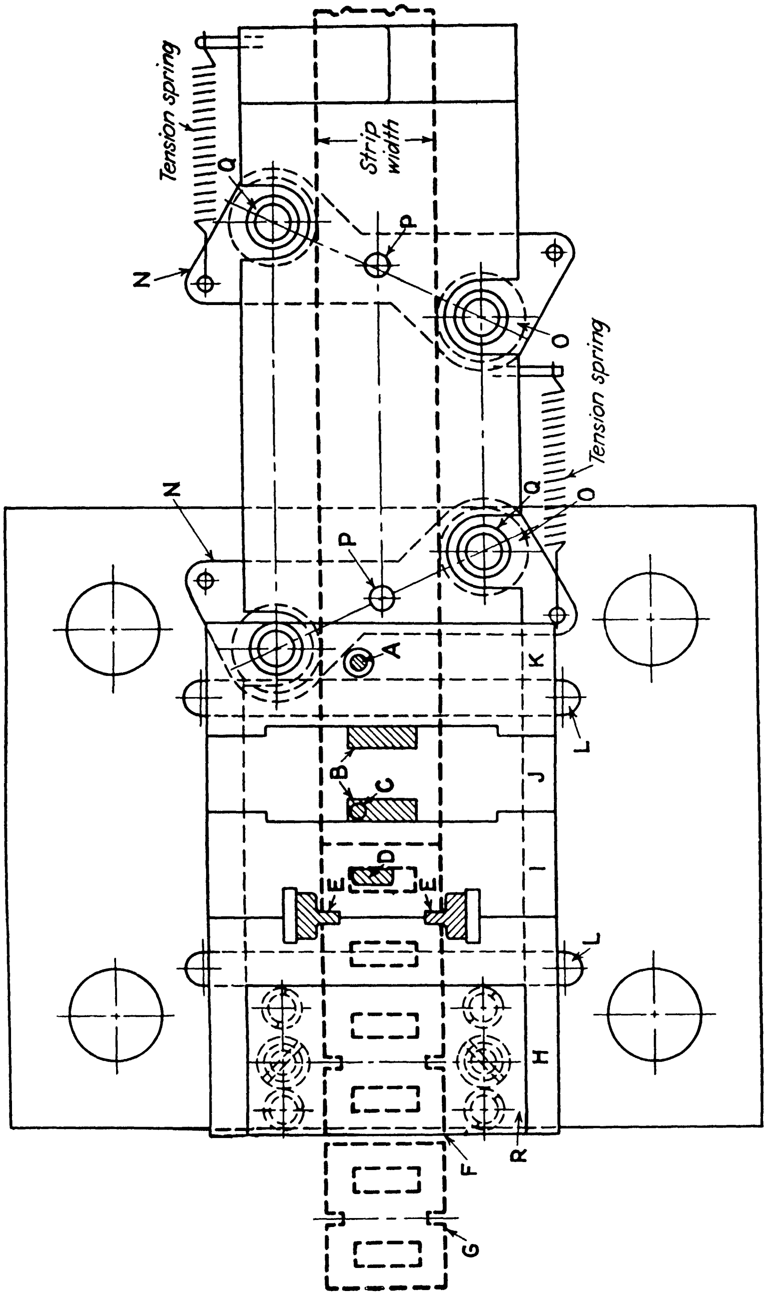
A Cut-and-carry Progressive Die of Unusual Features.—Figure 82 shows the design of a die that pierces a piloting hole at *A*; perforates two slots at *B*; pilots the work at *C*; stops the strip at *D*: notches at *E*; cuts off at *F*; and produces the piece shown at *G*. The pilot hole is pierced in the scrap of one of the slots and is subsequently cut out and falls beneath the press. This is a no-scrap die. The only waste is the five slugs which are cut out of the strip. The work material is 0.025-in.-gage hard-rolled steel. The finished work must be within close limits and be practically free of burrs. This is a sectional die. It is composed of four tool-steel sections: *H*, *I*, *J*, and *K*. There is also a cold-rolled steel extension table at the right. To centralize the strip, the table supports a positive channel stripper plate, in which are mounted two centralizing bars with rollers attached.

The die sections are secured on the shoe with screws and dowel pins and are prevented from spreading laterally by tongues milled under the end sections, as shown at *L*. The tongues are fitted closely within corresponding grooves milled across the die shoe. It is observed that all the sections are separated at such convenient places that the interiors of the die openings are easily exposed for the necessary grinding of their interiors. The die openings are section-lined in the drawing so that they stand out more clearly. At *M* is a side view of the notching punches for the dies at *E*. Here we see the back-up heels that guide these punches into the dies, preventing side movements and nicked cutting edges when making such "biting-in" cuts as these.

Feeding the Strip and Stopping the Press Automatically.—Strip is sometimes fed by rollers.* The strip comes from a coil of stock mounted on a reel. A free loop of strip is maintained between the reel and the rolls. A small reservoir, with a pipe attached, drops a lubricant on the strip just before it enters the dies. A limit switch, connected with the motor that drives the press, carries a current-cutting-off arm with an attached roller. The arm is actuated by a tension spring. The roller revolves in contact with the movement of the strip, so that when the end of strip unwinds from the reel, the tension on the arm is relieved, the current shuts off, and the motor and press stop automatically. When the operator is attending another press, the limit switch prevents the end of strip from entering the dies where half cuts and sheared and nicked cutting members in the die would result.

Parallelogram of Strip Centralizers.—Since the width of this blank and width of strip are equal, the width of strip as it passes over the dies

* See Figs. 139, 140, and 146.


Tension spring
Strip width
Q
N
P
O
Tension spring
Q
O
N
P
A
K
L
B
C
J
D
E
E
I
L
H
R
F
G

PLAN OF DIE

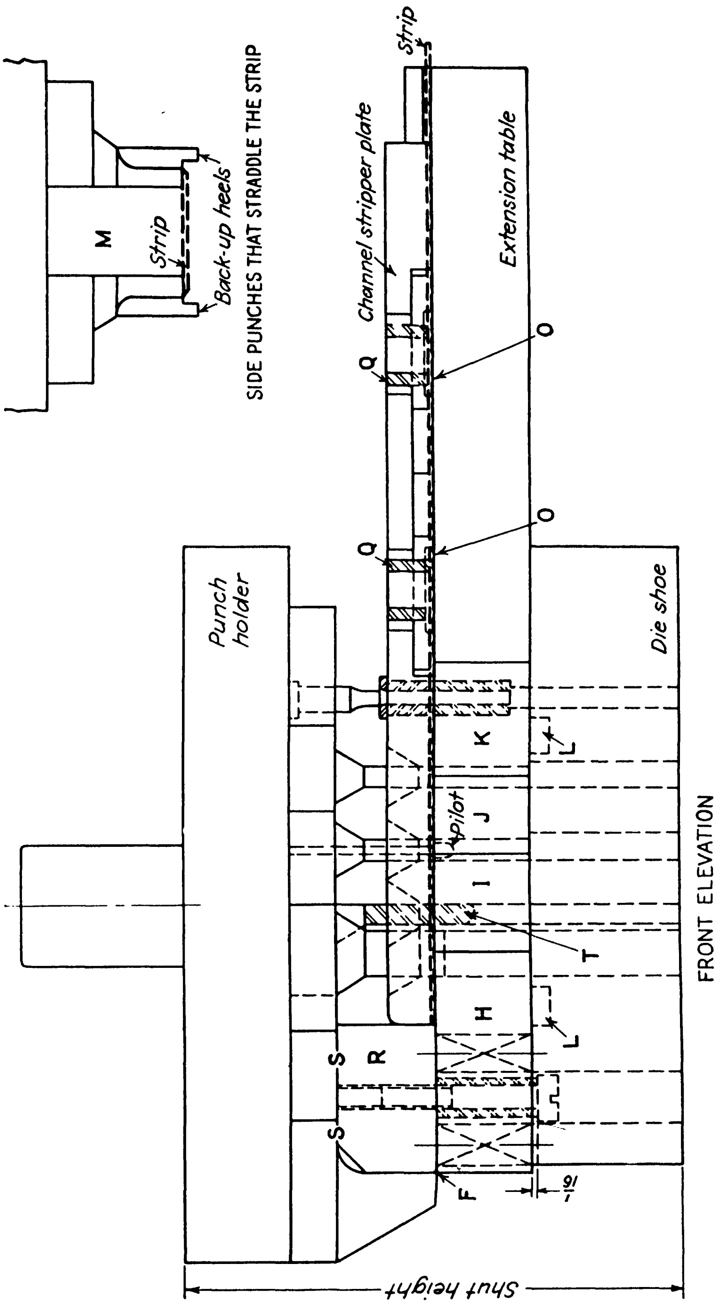


FIG. 82.—Design of a progressive die of the no-scrap type.

must be centralized if good work is to be turned out. This desirable feature is accomplished by the slight oscillating movements of the two lever bars *N*, which carry the four rollers *O* that straddle the strip, as shown. These levers are mounted on centering pins *P* and are actuated by coiled tension springs. A central stud, turned on each roller, is a running fit in steel bushings *Q*. Piloting of the work at *C* also helps to centralize the strip. It will be noticed that the levers are mounted in reversed position; that is, the rollers are located in a position that describes a truncated figure. This method of arranging the centralizing rollers has been found best for taking care of the commercial cross camber in the strips.

Spanking Out the Burrs.—It is a good die that can pierce and blank 80,000 pieces without beginning to "throw up" burrs objectionably high. However, this die is equipped with a "burr spanker." This makes it possible to run 150,000 blanks before it becomes necessary to remove the die from the press for regrinding the punches and dies. This device is shown at *R*. It consists of a tool-steel block attached over the die block at the last station. This block moves upward when the ram ascends, because of the pressure exerted by four compression springs. The block is halted in open position by the heads of two screws. The screws slide through bushings, as shown. The ends of the bushings are ground off, after grinding the dies, to keep them within a relative height with the die. The block rises just high enough to allow the strip to pass under it easily. In this case, it rises $\frac{1}{16}$ in. When the ram descends, the block is "spanked" down at point *S*. It then descends upon the work and flattens all the previously made cutting burrs, just before the piece is cut off.

An Automatic Stopping Punch.—For this high-speed die, when the strip is steadily advanced by a roll feed, a straight stop punch *T* can be successfully used. In this case the stop is positioned one station ahead of where the slot is perforated in the work: the slot in which the stop must engage to halt the strip for operations. The operating principle of this stop is as follows. If the stop is too long, it will descend too soon and will "jam" on the left side of the slot opening in the work. On the other hand, if it is too short, it will fail to descend soon enough and will jam on the right side of the slot opening. If the length of the stop is made between these two extremes, it will obviously enter the die without jamming the work and thus stop the strip correctly.

Dies of the type illustrated and described in this chapter can be run at the highest speed that the press will safely take. It is not uncommon to produce such work at the rate of 200 pieces per minute on a

No. 2 gap-frame press. On some of the modern high-speed presses or machines, a production speed of 1,000 strokes per minute can be steadily maintained for simple pieces of work.

High-speed Piercing, Notching, Cutting-off, and Forming Die

When Cut-and-Carry Dies Are Used.—High-speed progressive dies are best suited for large-quantity production of small nonferrous parts which are to be run almost continuously. Light-gage parts of steel are also fabricated in progressive dies, when the work thickness is under about 0.0625 in., and the size of the piece is within reasonable bounds, say about 4 in. long, 3 in. wide, and 2 in. high. These tools, which are sometimes called "cut-and-carry dies," are usually rather expensive to construct, but once they are built and put into action, 8 or 10 different operations can be rapidly and consecutively produced at each press stroke. Compared with the old-time system of piercing and blanking in the first tool, followed by four or five different dies and operations for drawing and forming the blank, cut-and-carry dies soon cover all their costs, if production is very large.

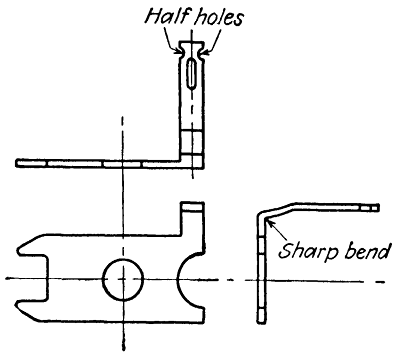
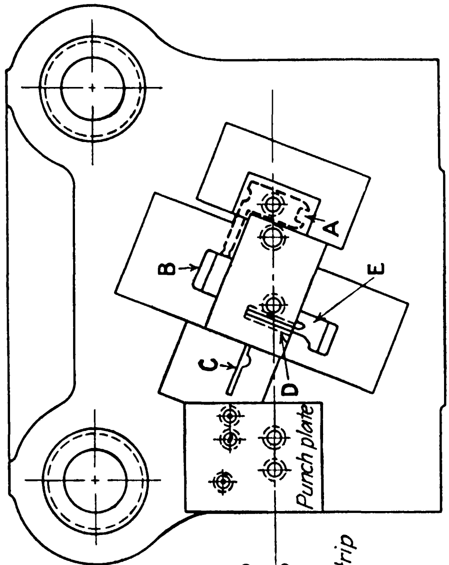


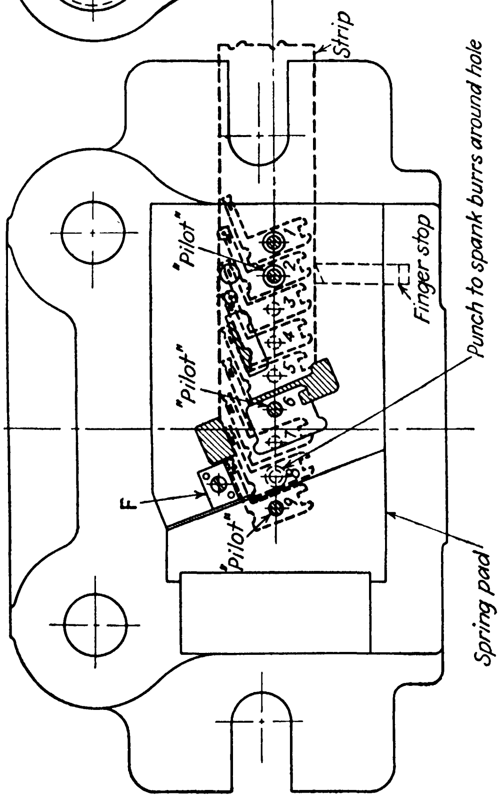
FIG. 83.—A brass terminal that is completed in one press stroke.

A Nine-station Progressive Die.—In Fig. 83, we have three views of a piece that is pierced, notched, blanked, formed, and ejected from the die completely finished, one piece per press stroke. Three views of the die used in producing this part are presented in Fig. 84. This die is run in a No. 2 or 3 gap-frame tilted press and can be operated successfully at the highest speeds these presses will safely take. In a modern high-speed press, this part could be produced up to 650 finished pieces per minute.

Description of the Die.—To save work material, the blank is positioned at an angle across the strip, as shown in the die plan. The die openings are section-lined to show them clearly. In stations 4 and 6, inserts are seen in the die. The inserts, with slightly tapered sides, are push-fitted from the bottom surface of the surrounding die block. The object in using inserts is to provide for easily grinding the interiors of die openings before assembling the inserts, so that the correct size and shape of the blank is accurately maintained all the way down



FACE OF PUNCH HOLDER



PLAN OF DIE

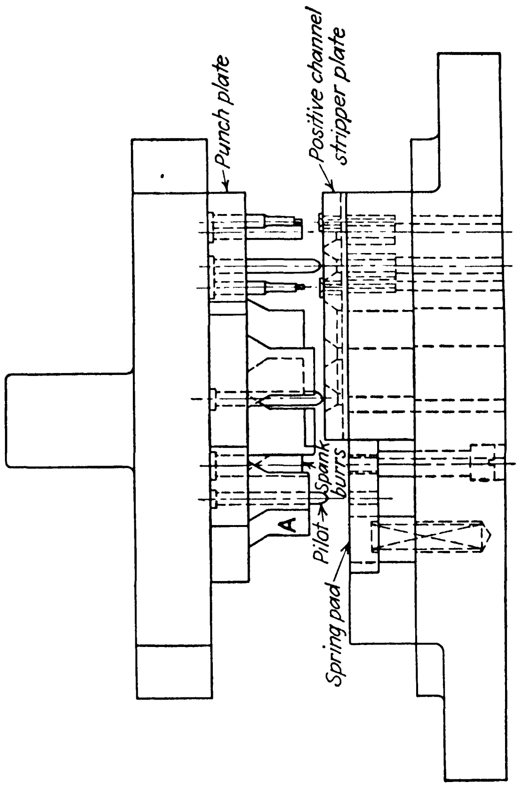


FIG. 84.—Design of a high-speed progressive die used in fabricating the brass terminal shown in Fig. 85.

through the die. The stripper plate is omitted in the die plan for the purpose of clarity.

Attention is now directed to the face view of the punch holder. Here, the arrangement of the punches is seen. Forming punch *A*, at the extreme right, the upper trimming punch *B*, and the long punch blade *C*, are the only ones in which the entire punch is cut from solid blocks of tool steel. The T-shaped punch blade *D* is held in a suitable slot milled in a holding plate. The lower trimming punch *E* must align with blade *D*. It also is machined from a solid block of tool steel. It fits tight against *D* and its corresponding holding plate. All the punches and plates are secured rigidly in place with socket-headed screws and dowel pins of suitable diameters. This view shows the punch-holder face as it would appear if lifted up from its normal position over the die, then turned toward the right, through an arc of 180 deg., to its present position beside the die plan.

In the view of the die plan, at station 1, the first hole is pierced. The strip is then advanced into station 2, and when the punches descend, a pilot engages in the hole for aligning the strip. At the same station, the first half-round notch is pierced in the blade of the work. This is a full hole, but it is subsequently trimmed across its center. All three of these die holes are "bushed" to permit aligning if distorted in hardening, or changing their sizes if such a necessity should arise.

In station 3, the elongated slot is pierced in the blade, and in station 4, the second half-hole is pierced in the manner just described for the first half-hole. The outline between two of the blanks is also cut by punch *C* in station 4. After another aligning pilot enters the hole pierced in station 1, stations 5 and 6 notch and cut the blanks apart by the descent of punches *D* and *E*. The only connection that now holds the blanks together is a small triangular area at the top of the strip. Station 7 is idle and so designed in order to provide sufficient steel between the die openings.

After the strip is advanced and the punches descend in station 8, a shouldered punch "spanks" the burrs around the hole, and punch *B* enters the die and severs the blank. The severed blank now lies on the spring pad in station 9. It is held by a pilot in punch *A*. This pilot engages in the hole. Punch *A*, continuing to descend, "throws up" the blade vertically, while holding the body of the blank firmly on the pad. The pad in descent forms the blade between the edges of the punch and die, thus finishing the piece as seen in Fig. 83. Block *F* is a stop that halts the strip in position for severing the last blank and forming the blade. On the upstroke, the finished pieces are freed

when the pilot in the forming punch leaves them on the pad. The pieces are then blown away by introducing a jet of compressed air. A light push-off pin in the forming punch prevents the pieces from adhering on the punch face.

Notice in the front elevation that the two punches for piercing the half-holes are guided through shouldered bushings press-fitted in the stripper plate; that they have short and "stubby" punch points; that only the body diameter above the points is guided in the bushings; and that a heavier body diameter above holds these punches in the punch plate by means of square-shouldered round heads.

The entering end of the strip is square. It is not necessary to cut off the end of this strip on a bias, as is usually done for work that lies across the strip at an angle. There is only one finger stop. It is shown in the plan; it halts the end of a new strip in the first station. A "sight hole" where the first pilot enters the stripper plate is used to pass the strip in consecutive order through to station 8 and against stop *F*. Thereafter, the power feed is applied, and the strip then runs through the die automatically. A roll feed is used similar to the one shown in Fig. 140.

Laying Out the Die.—The designing technique for high-speed progressive cut-and-carry dies is first to determine the size and shape of the blank. When the blank is not to be formed, these data are given on the piece part print. On the other hand, if the piece to be made is dimensioned as formed or drawn, it must then be "unfolded" and the dimensions determined for a flat developed blank. This procedure gives the developed width and all other data needed for designing the scrap strip. The scrap strip shows the sizes and indicates the shapes and positions of all the die operations necessary for completing the work. The procedure then is as follows: Lay out the die plan of the work in red dotted lines, showing the consecutive operations, as in the plan view of the die, Fig. 84. Draw the shapes and positions of all the cross-sectioned die openings. Project the die plan down below by showing the front elevation of the tool in its closed position. Show the positions of the punches and their corresponding die openings. Draw the projections in simple schematic forms for the purpose of obtaining a discussion sketch. If doubts arise of the feasibility of any of the operations, it is sometimes expedient to construct an experimental station and try it in the toolroom, before incorporating it in the die. Of course, this refers to new and untried operations.

These types of dies are used for fabricating a very large variety of small piece parts. The workpieces are usually parts of locks, small flat springs, clips, brackets, terminals, connector lugs, and small parts

used in the manufacture of light hardware and in the telephone and radio industries. In war work, there are innumerable pieces that cannot be made economically except in dies of these types; small parts in gun locks and belt links for machine guns are examples. These dies are always used for high production, in which coiled strip is fed into the die by roll, or hitch feeds. Shallow-drawing and channel-forming operations can easily be performed in their sequential order. However, these functions in progressive dies are often complicated by other difficult factors, which will be discussed later.

High-speed Piercing, Notching, Drawing, Forming, Blanking, and Straightening Die

This Die Produces 4,000 Pieces per Hour, One at Each Press Stroke

Small Die Work in the War.—There have been many good articles written on the subject of materials and tooling in wartime, but most of them refer to large press and die work, such as the heavy parts of tanks, airplanes, shell forgings, etc., while perhaps too little has been said upon the equally important subject of fabricating small parts. There are thousands of different piece parts to be made in 10,000 shops where light manufacturing is done, in order to satisfy the demands of war.

The design and operation of the progressive die under discussion far surpass those of ordinary cut-and-carry dies. It is a principle readily adapted for making a large variety of small parts for the war. After producing seven die operations, it delivers a completed piece in station 8, one piece at each press stroke. The press strokes are 60 per minute. The material strip is unwound from a large roll on a reel and is passed through the die by means of a "hitch-feeding device" (see Plate XVIII, p. 425), which is attached on the right end of the die shoe. A suitable lubricant is dropped on the strip just before it enters the dies. The press is run "wide open"; that is, the tripping pedal is held down continuously.

The piece produced is a radio part, called a "socket bracket." Dimensions and material specifications for the bracket are given in Fig. 85; an isometric view is seen in Fig. 86. The bracket is designed for holding two dielectric mounting plates in which are inserted the required number of contact jacks for making the usual base connections for a radio tube. The complete assembly is mounted on the radio chassis. In Fig. 87, the front elevation and plan views of the press tool are shown.

Operations at Stations 1 and 2.—In station 1, three round holes are pierced. The two diagonally positioned holes are $^{17}/_{64}$ in. in diameter,

and a portion of each hole is subsequently drawn and partially closed into the sides of the cup, and thus produce the two $\frac{3}{32}$-in.-radii openings in the edges of the finished piece. The third hole is $\frac{5}{16}$ in. diameter, is centrally located, and when the ram descends is entered by a pilot punch in station 2, thus securing a centralized registration of the strip. The progressive blanking center distance is 1.4375 in.

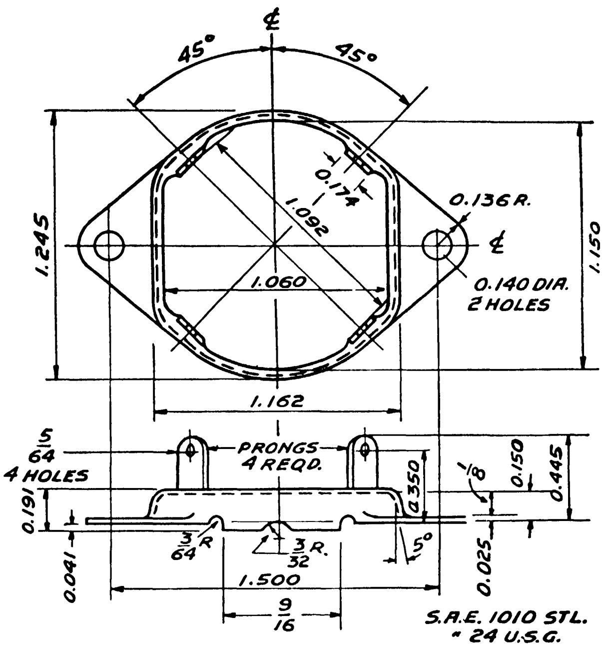


FIG. 85.—Dimensions and specifications of the work produced by the die shown in Fig. 87. The piece is called a "socket bracket."

Operations at Station 3.—After advancing the strip forward into station 3, a group of 10 round holes is pierced. The four 0.125-in.-diameter holes, after drawing and trimming, produce the $\frac{3}{64}$-in. radii each side of the $\frac{9}{16}$-in. length of the cup extension, shown in Fig. 85. The two holes shown on the 45-deg. line in the plan—station 3—are for piercing the two 0.140-in-diameter mounting holes in the work, and are subsequently entered by locating pilot punches for further centralizing the strip.

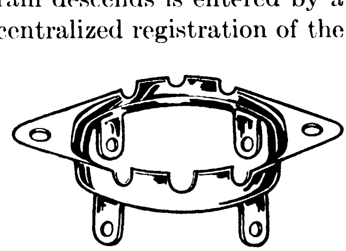
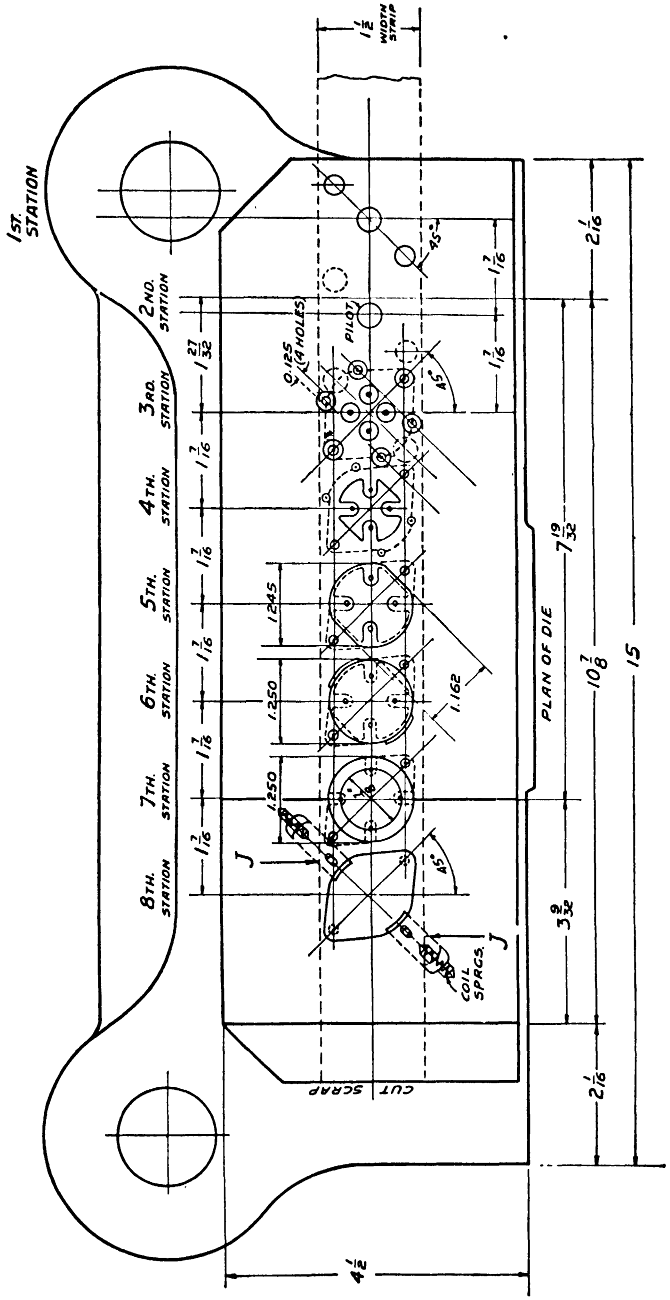


FIG. 86.—Isometric projection of the socket bracket for which dimensions are given in the preceding figure.


1 1/2 WIDTH STRIP
1ST. STATION
2ND. STATION
3RD. STATION
4TH. STATION
5TH. STATION
6TH. STATION
7TH. STATION
8TH. STATION
1 27/32
1 7/16
0.125 (4 HOLES)
PILOT
45°
1.245
1.250
1.162
J
COIL SPRGS.
PLAN OF DIE
CUT SCRAP
2 1/16
7 19/32
10 1/8
3 9/32
15
4 1/2

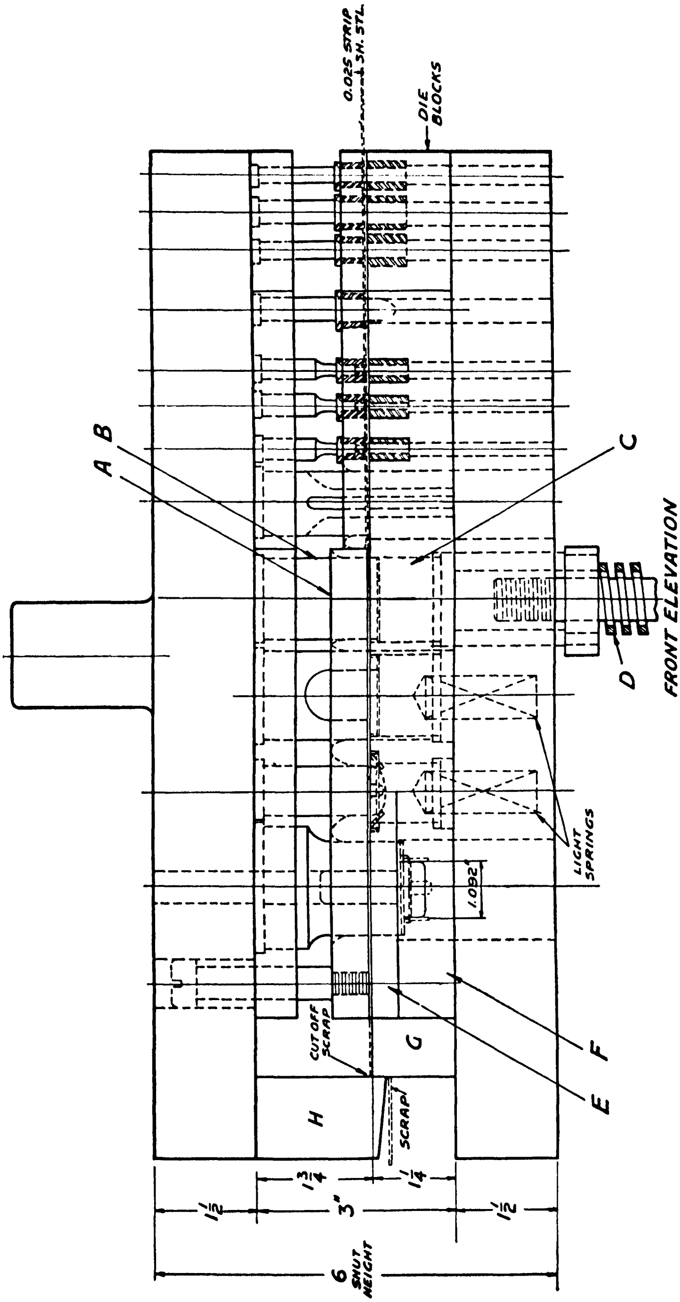


FIG. 87.—Drawing of a high-speed progressive die that completes nearly 4,000 pieces of work per hour.

The central group of four holes are each 0.078 in. diameter, and one of these holes is shown in each of the upturned prongs in Fig. 85. It should here be observed that each hole in this central group must be located and pierced so that, after a subsequent drawing and final bending operation, the specified 0.350-in. dimension is obtained in the finished piece. The piercing and pilot punches are all guided through hardened shouldered bushings. The bushings are inserted in the stripper plate as shown in the front elevation of the die. The stripper plate is the channel type and is positively attached over the die blocks.

Operations at Stations 4 and 5.—Station 4 cuts a "cross-shaped" blank from the center of the work, which leaves the contours of the four prongs intact. This blank is waste and is pushed through the die by the punch. When advancing the strip into station 5, it passes out from under the positive channel stripper plate and enters under the spring compression pad *A*, which is attached on the punch holder, as shown in the front elevation. At this station the cup is drawn, and the spring-pad pressure "irons" the wrinkles from the material while the cup is being forced to enter over the edge and into the drawing die by the descent of drawing punch *B*. The ends of the four prongs are necessarily drawn away from each other in this operation, as shown in the plan view of the die.

The drawing die is fitted with a spring shedder *C*. This shedder registers on the die shoe at the completion of the press stroke and draw. The shedder is of sufficient length to allow drawing and "spanking" the cup to the given depth of 0.150 in. When the ram ascends, the shedder, being actuated by compression spring *D*, follows up the work and ejects the drawn cup from the die. At the same time, the cup is stripped from the drawing punch by the action of the compression pad *A*. These well-known die features allow the strip, with cup attached, to be further advanced across the die without interference.

Operations at Station 6.—The strip and cup are now advanced into station 6, where the first trimming operation occurs. The drawn cup falls into position in the 1.250-in.-diameter hole shown in the die. The work is constantly being centralized by the descent of pilot punches that enter the two 0.140-in.-diameter holes previously pierced in the strip. The sixth operation is shearing through the $\frac{9}{16}$-in. width shown in Fig. 85. A spring shedder, similar to the one described in the station just previous, together with spring pad *A*, ejects and strips off the work when the ram ascends.

Operations at Station 7.—Station 7 is practically idle. The main die block terminates here. This precaution in design shortens the

block and avoids hardening difficulties that may occur when too many stations are located in one block. This idle station also separates the cutting edges between the previous trimming operation and the last station, which is blanking. However, a very light operation is performed at this station. The four prongs, which are finally bent straight down in the last station, are partly bent here. A spring shedder also raises the cup from the die, as at two previous stations.

Operations at Station 8.—The contour of the blanking die in the eighth and last station has the same outline as the finished piece. The punch is relieved on opposite sides, however, to admit drawing up the two 9⁄16-in. widths of cup wall extensions. This occurs when the blanking punch, in descent, cuts the piece from the strip and then forces it down through the die, thus drawing up the extensions. In the face of the blanking punch is inserted a shouldered pilot. The larger shoulder fits within the contour of the cup. The smaller diameter of the pilot is 1.092 in., which corresponds with the distance between the prongs; it enters the cup first and bends the prongs straight down, just before blanking occurs.

Blanking die *E* is a hardened plate and is only 3⁄8 in. thick. It is supported by the cold-rolled steel block *F*. The blanking punch is of sufficient length, when the punch is at its extreme descent, to force the work below die plate *E*, after blanking. In ascent, the finished piece is stripped from the punch by contacting the under edges of the two spring latches *J*, as shown at opposite sides of the blanking-die opening. The work is then free to fall through the shoe and beneath the press.

Scrap cutting blades are shown at *G* and *H*. As the work is advanced over the dies, these cutters clip the scrap strip into blanking lengths at each press stroke. The cut pieces slide through a chute into a barrel placed near the press.

Grinding Progressive Dies.—When necessary to grind the blanking die, block *F* is "shimmed up" correspondingly. Bushings are inserted in the die blocks for piercing all the round holes. These bushings are press fits and are surface-ground in the blocks. The piercing punches are of equal lengths to expedite grinding them. The proper relation between all working surfaces can easily be maintained throughout the life of this tool. All the cutting members are made of a special grade of high-speed steel, and between 100,000 and 150,000 pieces can be produced between grinds.

Using Progressive Dies for War Orders.—Cut-and-carry dies of the type just described are especially economical press tools to use in producing a very large variety of parts for war equipment. They are used mostly for small parts, but such parts are just as necessary

as tank seats and airplane fuselages. They can be designed for the rapid production of primer caps and cups, rifle components, parts of range finders and bomb sights, airplane strut seats, dial indicators, machine-gun links and parts, clips for rifle cartridges, time and contact fuse parts, magazine feeding devices, gas-mask stampings, instrument parts, connector lugs and terminals, switchboard parts, detonator parts, and for an endless variety of communication sets used in the telephone and radio.

High-speed Piercing, Blanking, Notching, Splitting, Indenting, Spanking, Forming, and Cutting-off Die

General Order of Operations.—This cut-and-carry progressive die pierces four holes, cuts a waste blank and two notches, splits apart

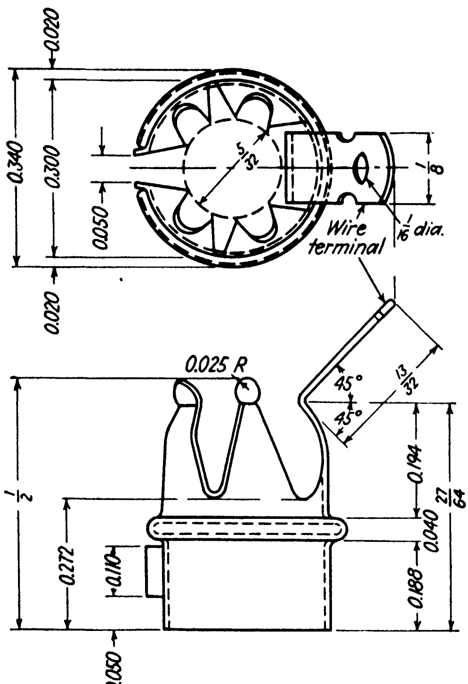


FIG. 88.—A brass spring jack to be completed in a progressive die, one piece at each press stroke.

two of the work blanks, forms two end lugs and five prongs, indents a long semicircular bead and "spanks" it to size, curls the work body U-shaped, curls it again into a circle, and then cuts the scrap strip apart, separates the pieces, bends an angle in the side terminal. and

finishes one completed piece at each stroke of the press. The pieces are blown from the die, by compressed air, and out at the rear of the press.

Description of the Work.—In Fig. 88 are two views for a "center prong" made from No. 26 Brown & Sharpe gage (0.0159-in.) brass. It is to be produced in a die, one finished piece per press stroke. This piece is a "spring-jack"; it is a patented article and is inserted in a socket plate and used for making contact with the center stud of radio tubes.

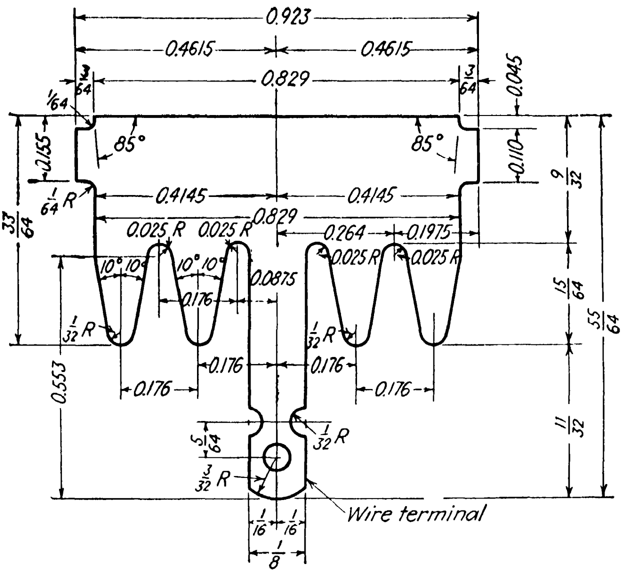
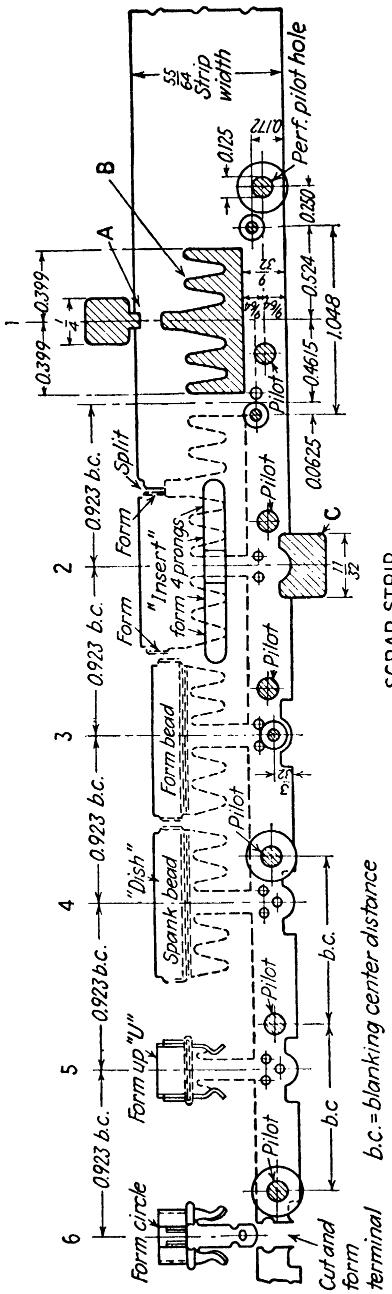


FIG. 89.—Blank development for the spring jack.

Developing the Blank.—The first procedure in designing the die is to develop the blank, as shown in Fig. 89. The finished piece must be literally "unfolded and dimensioned," as seen in the figure. In this particular case, the center line within the material thickness is taken for the neutral bending line. For such small parts, it is best to lay out the blank five sizes. This is done by laying it out 10 sizes on a half-size scale. All possible working dimensions should be given for the blank, as computed from those given in the finished piece, Fig. 88, because the blank dimensions determine those for the scrap-strip and for the jig-boring layout.

Developing the Scrap Strip from the Blank.—Next, the scrap-strip layout in Fig. 90 is made. Here is where the designer's previous experience in this work counts most. He must know which of the operations should be done first, and why certain other operations are



SCRAP STRIP
Die openings are section lined

FIG. 90.—The developed scrap-strip layout.

the best ones to follow with in consecutive mechanical order. It is always safe to start by piercing a pilot hole, so that the strip can be realigned with a pilot punch, immediately following.

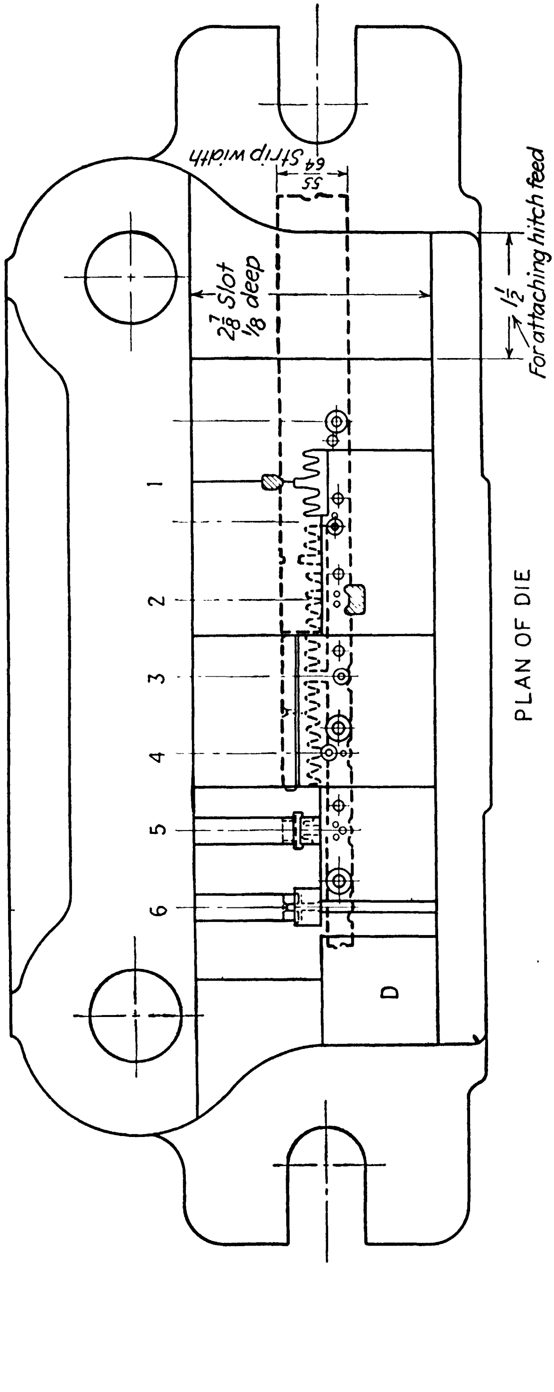
It will be observed that the blanking center distance between stations is 0.923 in., which is the same as the developed length of the blank. The pilot holes are made larger, and therefore more serviceable, by piercing them in the scrap outside the workpiece. The $\frac{1}{16}$-in.-diameter hole in the wire terminal cannot be used for piloting, first because it is too small, and second because in the last station the work is severed from the strip, and the terminal is formed at an angle. The die-block sizes, their hardening problems, and separations between the blocks must be considered, together with proper facilities for grinding the punches and dies after they become dull. It is frequently necessary to change, or lay out the scrap strip possibly a half dozen times, before the most practical layout is discovered.

Detailed Order of Operations.—First of all, it should be borne in mind that following the 0.125-in.-diameter pilot hole, perforated at the beginning of station 1, a "bullet-nosed" pilot punch enters this hole at each station, and all round punches are guided through bushings in the stripper plate. The purpose of this is to align the strip and work before any of the punches begin operations on the strip. When the ram ascends, the work is stripped from the punches by a positively attached channel stripper plate that includes station 3, as shown in the front elevation, Fig. 91. Stations 4, 5, and 6 do not require "stripping" of the punches.

Referring to the scrap strip, Fig. 90, station 1 takes care of $1\frac{1}{2}$ pieces of the work. One 0.125-in.-diameter hole and two $\frac{1}{16}$-in.-diameter holes are pierced, and the latter holes are subsequently cut across to make the half-holes in the wire terminal. A notch is also nipped out between the blanks at *A*, and a waste blank is cut and pushed through the die which outlines the four prongs at *B*. All side cutting punches, as at *A* and *C*, have "back-up" heels that enter the dies $\frac{3}{16}$ in. before any cuts begin. This feature prevents the cutting edges of the punches from deflecting and thus avoids injuring cutting members.

The blanks are split apart in station 2, and the cut ends or lugs (0.110 in. long, Fig. 88) are formed up. An insert in the die also forms the ends on four prongs by using a suitable punch attached on the punch holder; also notching punch *C* cuts the $\frac{3}{32}$-in. radius on the wire terminal end.

In station 3, the length of the bead that surrounds the workpiece is indented and formed. This is done by a "blade-nosed" punch that



55/64 Strip width
2 7/8 Slot
1/8 deep
1 1/2
For attaching hitch feed
1
2
3
4
5
6
D

PLAN OF DIE

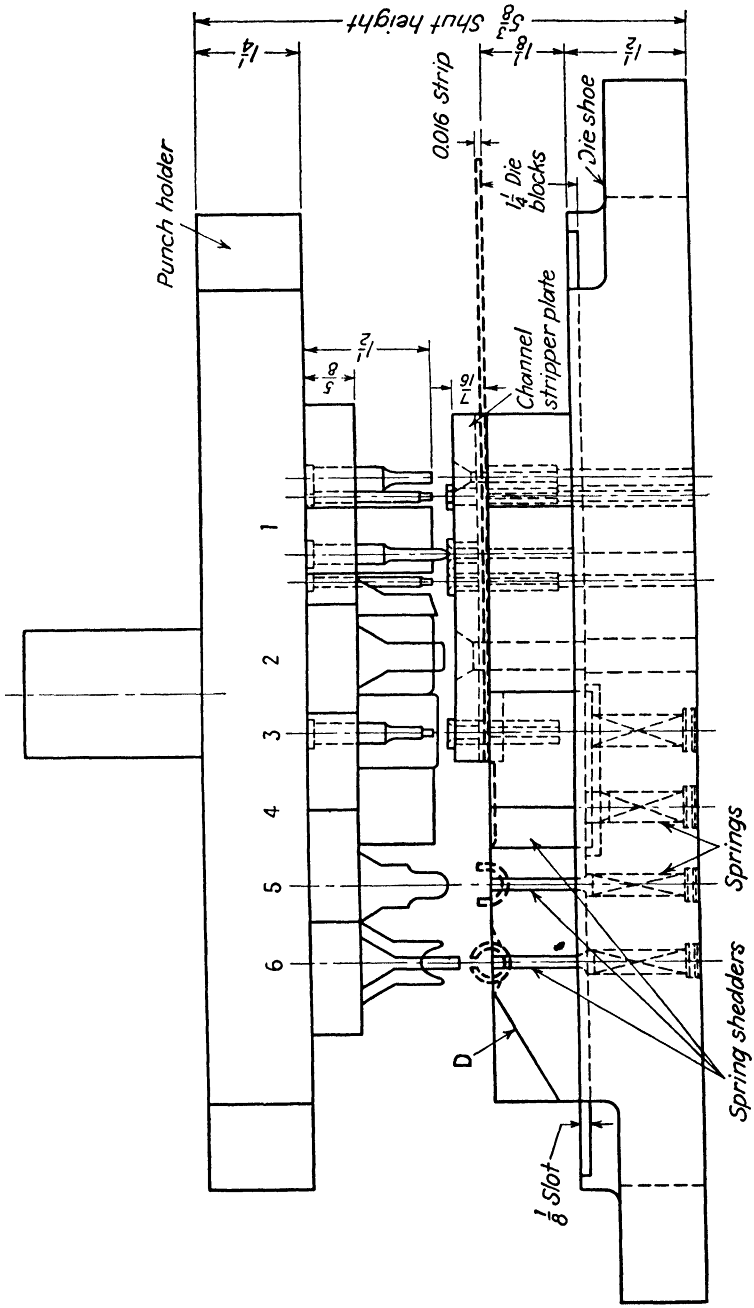


FIG. 91.—An unusual cut-and-carry progressive die. This die was a difficult one to design and build.

pushes the metal down into a slot cut in the die. A "spring shedder" blade in the die, under stations 3 and 4, ejects the work when the punches ascend. (See front elevation, Fig. 91.) The $\frac{1}{16}$-in.-diameter hole is pierced in the center of the wire terminal end.

At station 4 the bead just formed in the previous station is "spanked" down into a narrower slot cut in the die. This "sizes" the bead to the 0.040-in. dimension shown in Fig. 88. A spring shedder blade ejects the work from the die.

At station 5 a semicircularly faced punch, in descent, forms up the work U-shaped, in a die cavity. A spring shedder ejects the work from the die.

An angular punch blade, $\frac{1}{8}$ in. thick, descends at station 6, together with a semicircular cavity punch. The blade severs the scrap strip, cuts the wire terminal to its specified width, and forms the 45-deg. angles in the terminal, as shown in Fig. 88. The cavity punch curls the body of the work into circular form and thus completes the piece. A small lug, 0.050 in. thick, shown inserted at the center of the punch cavity, prevents the curling punch from closing the circle entirely and gives the specified 0.050-in. opening shown in the finished piece. The cut scrap pieces are separated from the work by sliding down a ramp, as shown at *D* in the die drawing, Fig. 91. When the punches ascend, a jet of compressed air, aimed through a nozzle, blows the piece from the die into a container at the rear of the press. The fifth and sixth operations are plainly shown in the front elevation of the die, Fig. 91.

Designing the Die.—Figure 91 shows the plan and front elevation views of the assembled die. The stripper plate has been omitted in the plan to show all the die stations. All the die openings are section-lined, and die bushings are inserted for round holes, if there is sufficient space for them. Bushings in the dies can be removed easily for changing the sizes of their center holes, or to correct the positions of holes that may have moved slightly or which have distorted in hardening.

The die set is one of the long narrow types, with two guideposts in the rear. The die sections are closely fitted within a slot milled $\frac{1}{8}$ in. deep throughout the length of the die shoe. This precaution prevents the die sections from spreading transversely. Two screws and two dowel pins, not shown, but for which space has been allowed in the blocks, enter through the bottom of the shoe and rigidly secure each die section in the slot.

Attention is now directed to the several separations between the die blocks. The blocks are divided in such a manner that the interior of the die openings is exposed for grinding easily after hardening.

This ensures uniformity in the die size all the way through the blocks and thus provides a long "life" for the tool. It is not uncommon to use such dies after more than ¾ in. has been ground from the faces of both the punches and dies. This means that the tool will still be in use after 150 "grinds" of 0.005 in. each. Furthermore, it means that between 40 and 50 million pieces can be produced before the die must be rebuilt.

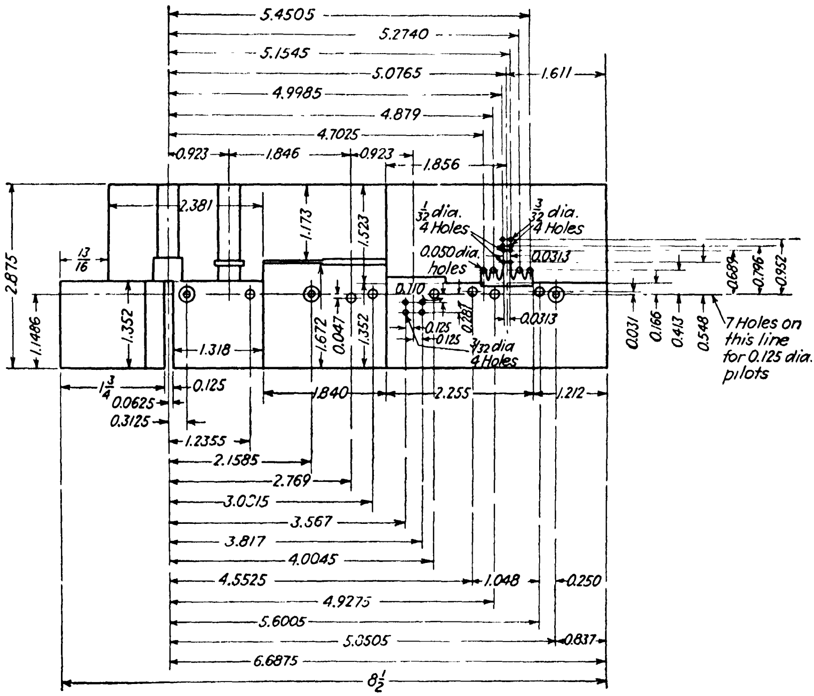


FIG. 92.—Jig-boring layout for the progressive die shown in Fig. 91. It is a typical layout of this character.

Jig Boring the Die Blocks.—Much time and unnecessary expense can be saved in the construction of progressive dies if the toolroom has a jig-boring machine. The tool engineer furnishes a jig-boring layout, a sample of which is shown for this die in Fig. 92. The die blocks are clamped together on the table of the machine, and each of the given sizes of holes is drilled. An allowance is usually made for boring the holes and grinding the interior of the dies.

Jig-boring dimensions must be given from left to right, and from the tops of the blocks down to each of the hole centers. They may also be given from any important vertical line, and from an important horizontal line, each way, to the center of each hole. If given

any other way than just mentioned, it will be necessary to refigure all of them, because the positioning of the work and dimensions would not correspond with the direction of the table feeds on the machine.

Jig-boring dimensions are determined by those given in the blank development, in connection with the scrap-strip layout, and with the distances added from the first hole to the edges of the blocks. The blanking center distance, and multiples of it, are frequently involved. After the blocks are drilled, and the holes bored where possible, the irregular openings are sawed out on a band saw, and then the contour is filed to line on a die-filing machine. Some of these layouts are quite tedious to dimension. They may have 100 or more dimensions, with many of them to be determined by using trigonometric triangulation. In some layouts, allowances are necessary for bending angles in the work between the holes, and the angles are subsequently formed, so the dimensions between holes must be absolutely right.

High-speed Notching, Piercing, Side-forming, Folding, Spanking, and Cutting-off Die

Functions of "Cut-and-carry" Dies.—Any operation that has ever been produced in other small types of press tools, regardless of complications, can also be performed in well-designed cut-and-carry dies. Moreover, the operations can be performed at higher speeds and with more certainty.

If there exists any such thing as a "sure-shot" tool, this type of die most nearly approaches it. In the production of small intricate parts, these dies easily outclass all other types of dies because, with them, one completed piece can be finished at each press stroke, and this is the highest tool efficiency attainable. There is apparently no limit in the variety of operations that these tools can be made to do, excepting heavy-gage materials and too large pieces of work.

It is not unusual to produce millions of formed pieces, each within limits of plus or minus 0.001 in., and even better than that has been done. Therefore, these tools are admirably adapted to the light manufacture of precision parts used in war communication and other instrument sets, and for parts that enter into light portable armaments. Progressive dies are an important factor in furnishing hundreds of millions of the necessary items used in fighting a victorious war; they may be just as important as the so-called "Guerin process" used for blanking and forming a few thousand airplane parts, in rubber pad dies.

Production necessarily varies with the shape of piece, kind of materials, and the size and speed of the press used. In an ordinary gap-frame press, 150 pieces per minute have been done, on a con-

servative basis. In the Multislide machine, 125 to 300 pieces per minute, and in some of the modern high-speed presses, more than 1,000 pieces per minute, of simple parts, have been run. One case of multiple blanking small transformer laminations, four pieces per press stroke, made 4,000 parts per minute and stacked the pieces in delivery chutes.

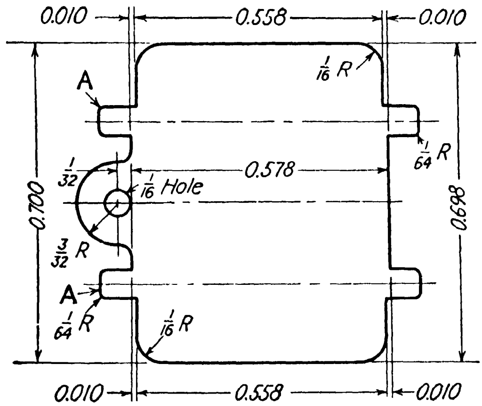


FIG. 93.—The blank development from which the scrap strip is designed.

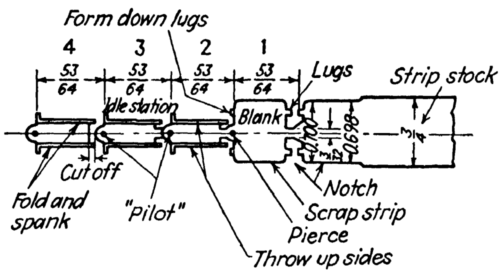
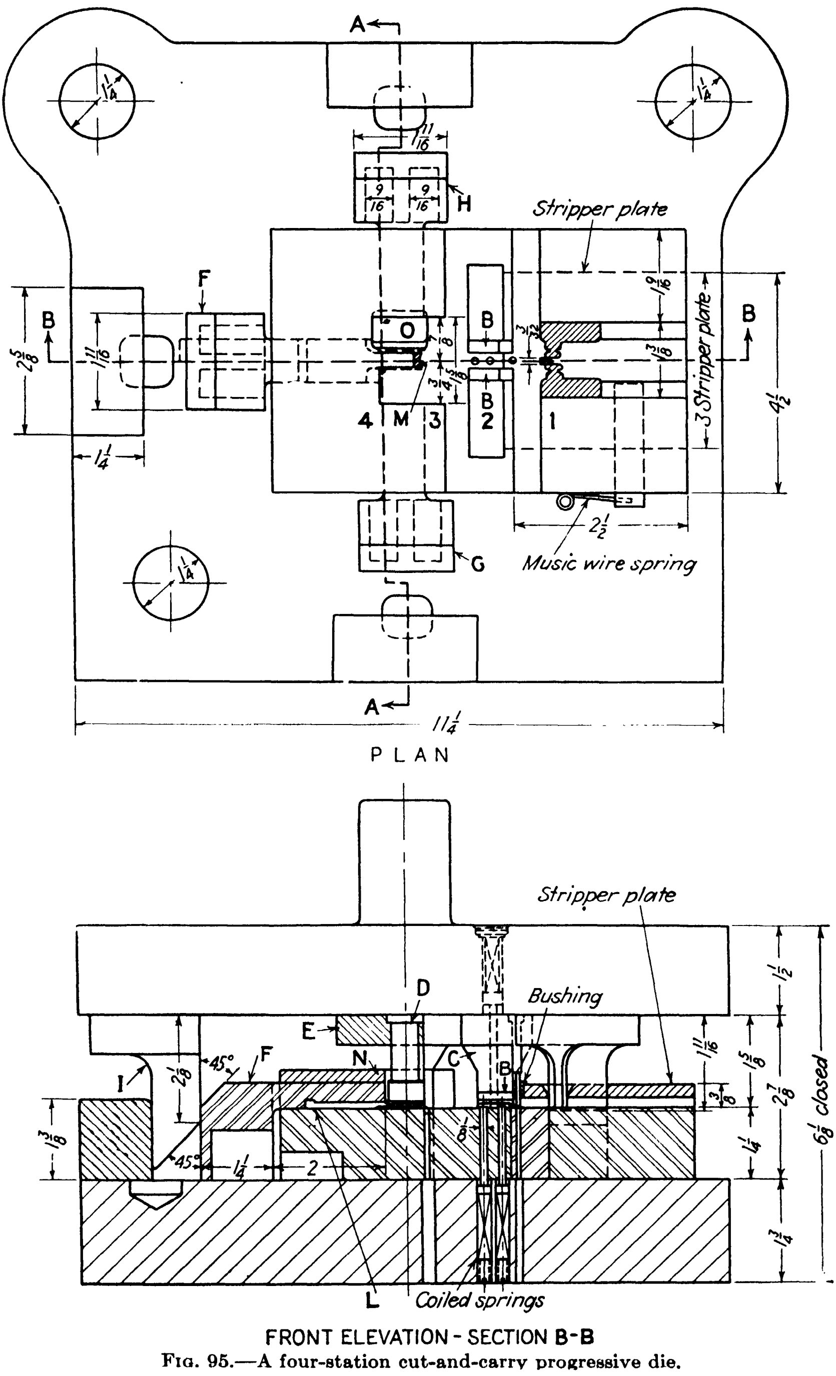


FIG. 94.—The scrap-strip design.

In some shops where progressive dies are built, only one or two designers and a few diemakers have had sufficient training and experience in handling these designs or in the proper technique for building the tools. Some diemakers seem to possess a special "gift" for this kind of work. However, it is because of these difficulties in designing and construction, and the lack of general knowledge on the subject, that the present discussions are said to be timely and useful to the industry.

Rectangular Coil Core Made in Progressive Die.—The blank development for the coil core is shown dimensioned in Fig. 93. This sketch is the result of having "unfolded" the piece part (drawing not shown) into a flat blank contour. Figure 94 shows the scrap-strip



FRONT ELEVATION - SECTION B-B

FIG. 95.—A four-station cut-and-carry progressive die.

design; this layout should be made after sketching the blank. The scrap strip determines all the necessary operations at each one of the stations, and shows why the operations must follow one another in a certain order. When starting with the correct scrap strip, the layout of the die is well begun. All that remains to be done is to lay out the die sections and punches, select the die set, and then complete the assembly drawing. Dimensions in the scrap strip are based on those of the blank. The station-to-station blanking center distances are $^{53}\!/_{64}$ in., as shown. Designing the scrap strip, and using a practical sequence of die operations, is a real test of the tool engineer's experience, ability, and skill.

Progressive Die Operations.—The notches are cut at station 1. This outlines the contour of the blank at each of its ends. The strip is also trimmed on both edges; the trimming is combined with the notching punches. These punches are provided with "heels" that enter the dies ahead of the cutting faces and guide the punches ahead of the cut, thus avoiding inaccurate work and chipped-off cutting edges. Trimming reduces the strip width from $^3\!/_4$ in. to the tapered width of the blank, 0.698 and 0.700 in.

At station 2, two lugs *A* are formed down, the $^1\!/_{16}$ in. diameter-hole is pierced, and the sides of the work are "thrown up" to form a channel. Attention is here directed to the method employed in forming up the channel. The trimmed blank is advanced from station

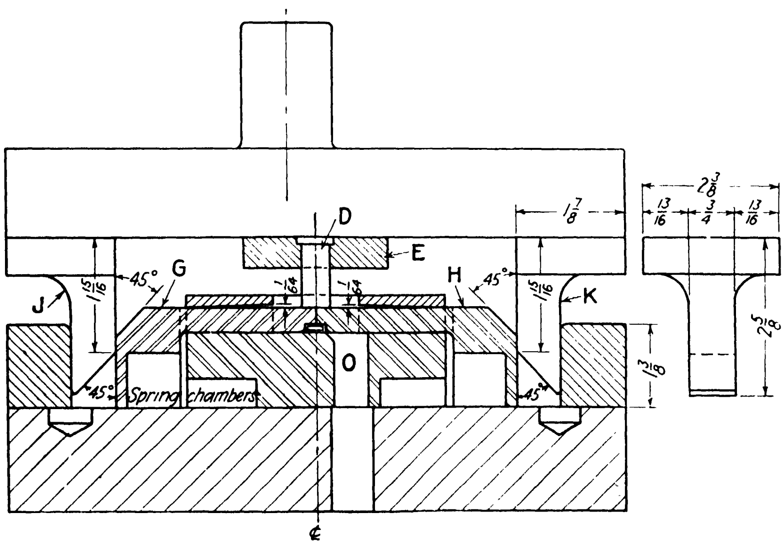


FIG. 95.—(*Continued.*)

1, along with the strip, by the $\frac{3}{32}$-in. connecting neck which has been left between the blanks for this purpose. In Fig. 95, which is the plan and front elevation views of the die, at *B*, is an elevated "ramp" over which the blank is advanced into station 2. The ramp is a shallow channel, having an open width that corresponds with the outside width of the formed-up coil core. The blank now lies on top of the ramp, and is slightly elevated above the surface of the surrounding die blocks. Punch *C* has the same cross width as the interior of the coil core channel. When punch *C* descends, it throws up and forms the sides of the core channel by pushing it down into the channel in the ramp.

When the punch ascends, two push-off pins, actuated by coiled springs in the die shoe, follow up under the work and eject it from the

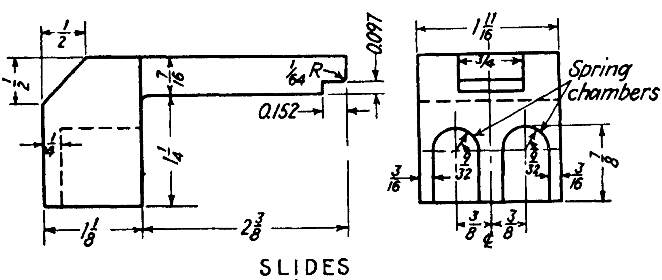


FIG. 96.—Details for one of the side forming and spanking slides.

ramp. Likewise, another spring push-off pin, inserted vertically through punch *C*, "strips" the work from that member. The strip and work are now ready to be advanced into station 3.

Station 3 is an idle station. It is made so for the purpose of providing sufficient space between stations 2 and 4 to attach punch *C* and punch *D*, with its retaining plate *E*, in station 4.

At station 4 the coil core is formed completely and cut off, finishing the piece. When the strip and work are advanced into this station and the punches descend, three cam-actuated slides *F*, *G*, and *H* are advanced by the descent of side cams *I*, *J*, and *K*, respectively. Slide *F* advances first and pushes the inserted blade *L* into the open channel in the core. The size of this blade corresponds with the specified width and length of the core interior. Side cams *J* and *K*, continuing to descend, force the notched ends (0.097 by 0.152 in., see Fig. 96) on slides *G* and *H* over the work and blade *L* and, in doing so, bend the sides of the core channel 90 deg. toward each other. The core body is thus formed into rectangular shape. The work is cut to length by a trimming punch that enters the die opening *M*.

Sizing and Finishing the Work.—Now comes the important feature in the design of side-cam dies of this type. Slides *G* and *H* are each allowed approximately 1/64 in. freedom in vertical movement. When the ram descends within 1/64 in. of its maximum downstroke, and continues to descend, punch *D* "spanks" down the slides and thus "sizes" the rectangular opening in the work around blade *L*. This feature is clearly shown in the sectional view *A-A*, in Fig. 95.

When the ram ascends, compression springs cause the three slides to recede. While blade *L* withdraws from the work, lugs *A* contact the right face on the slide retaining block *N* and thus strip off the finished work. The piece is blown from its stripped position by compressed air; it falls into the slanting hole *O*, cut through the die shoe, and then down into a container beneath the press.

Progressive Die Sets.—For pressworking light-gage materials, the punch clearances are usually so very close (6 per cent of the material thickness, or 3 per cent all around the punch) that it is best to specify four-post die sets. This ensures accurate guiding of punches into the die openings. In Fig. 95, a standard two-post set is used, but, as an extra precaution, a third post is added at the front on the left-hand side of the die set, as shown.

Strip Feeding of Progressive Dies.—Today, with the many classes of war priorities issued on important commodities such as coiled strip steels, the strips must be used, if at all, either in 8- to 10-ft. lengths or with welded-together ends to make one continuous roll of coiled stock.

With regular strip of coiled stock, the feeding of small strip is done by passing the strip through a "hitch-feeding" device attached on the right end of the die shoe.* Steel strip is passed between two felt pads saturated with oil and then enters under the stripper plate and over the dies. Lubricants are necessary when blanking or drawing sheet metals for the same reason as in a bearing, to prevent metal-on-metal contact between moving parts. Dies will stand up better, require less grinding and repairs, and therefore last much longer, when the strip is properly lubricated.

FOUR CUTTING AND THREE BENDING OPERATIONS IN ONE PRESS STROKE

An Adjustable Cut-and-carry Die

An Unusual Press Tool.—A single-operation progressive die, that trims, perforates, shears, performs a first and second forming operation, cuts off, and then performs a third forming operation on four sizes of

* The hitch-feeding device is illustrated and described in Plate XVIII, page 425.

the small frames of the design shown in the upper views of Fig. 97, is illustrated in Fig. 98. The frames are made from mild steel, 0.0375 in. thick, and are used in assemblies for covering and mounting small transformer coils. The trimmed blank is shown in the lower view, Fig. 97. The same blank as it appears after the first and second forming operations is shown in the central view, while the two views

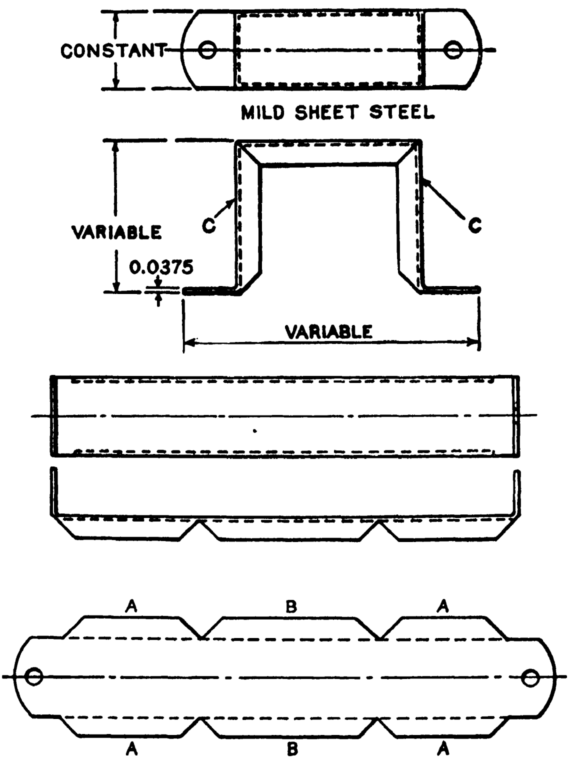


FIG. 97.—(Upper views) One of four sizes for small transformer-coil frames produced in the die shown in Fig. 98. (Lower view) The blank and partly formed frames.

at the top show the blank after the third forming operation, which finish-forms the frame ready to use.

The Adjustable Feature.—Four lengths and heights of frames are made by the tool or progressive die shown in Fig. 98. This is accomplished by changing the shearing punches *D* and *E*, each of which is made in rights and lefts, and by adjusting the positions of parts *F*, *G*, *H*, and *I* in their respective dovetailed slots and clamping them by screws in *S* and *J*, after inserting pins in the locating holes. The other members at *K*, *L*, *M*, *N*, *O*, and *P* are also changed or adjusted to suit the size of frame.

To avoid confusion of lines, only the principal working members are shown. The spring pads *N* and *Q* are prevented from being tilted when the angular shearing punches *D* and *E* come in contact with them, by providing idle punches that are brought into contact with the pads on the sides opposite the shearing punches. The stripper plates are not shown in the plan view.

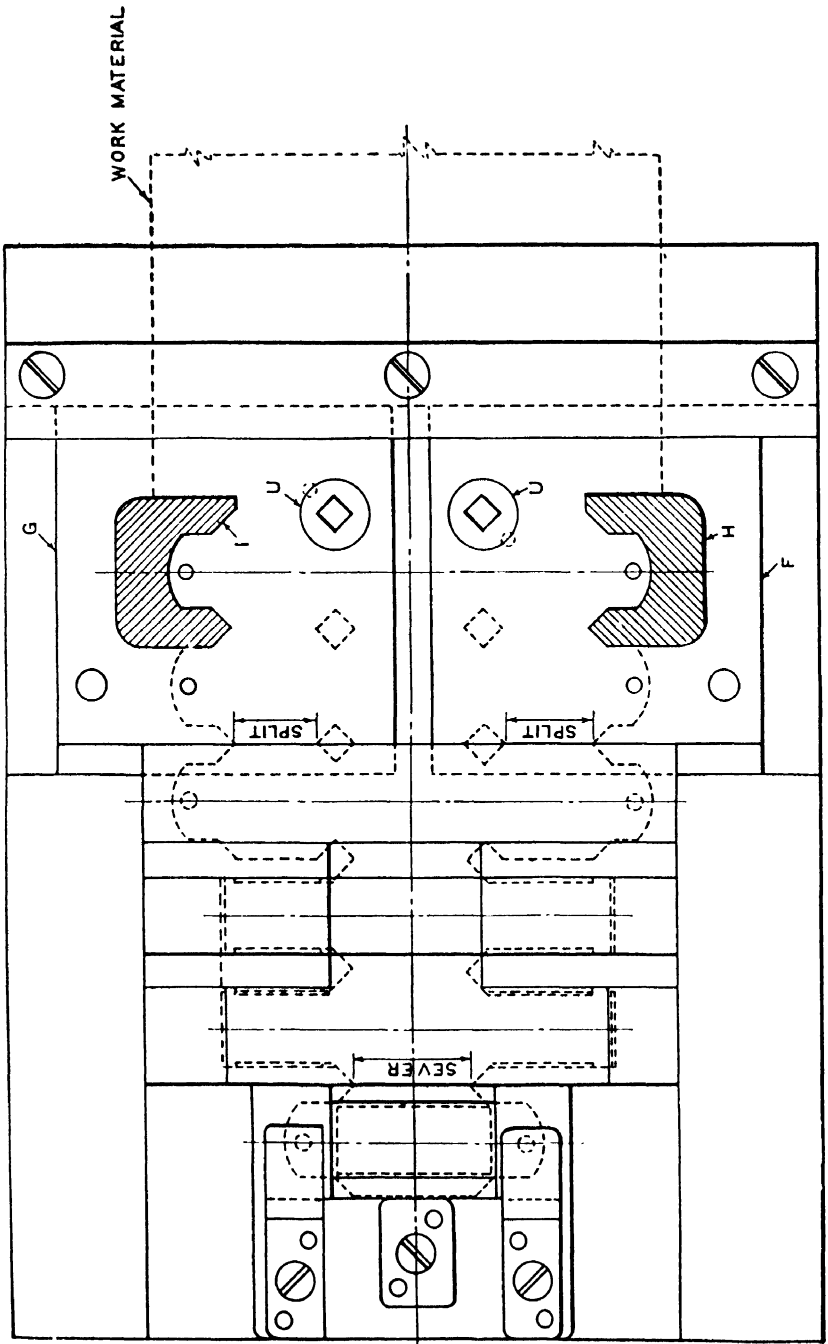
The Strip.—The work material is sheared in widths that allow 1/4 in. scrap on each side of the trimming dies. The two trimming punches *H* and *I* have the usual backing-up heels, which, in dies of this character, prevent the punches from shearing or nicking the die edges when cutting into the strip. The two 1/4-in. scrap strips and the small perforated slugs are the only waste, and these are pushed through the dies, leaving no loose pieces or strip on the surface to interfere with the punch operations.

Order of Operations.—While this tool may appear complicated or impractical, it is operated continuously with no more trouble than other tools or dies of more simple design. When the tool is in use, the strip is entered from the right, under the open-side stripper plates *T*, and moved to the left until its forward end comes in contact with the first finger stop (not shown), conveniently placed for locating the stock for piercing the square holes in the bushings at *U*.

Next the strip is advanced against the second stop and the outer ends are trimmed and perforated, after which the forward end is split from the outer diagonal corners of the two square holes through to the outside edges by two punches *D*, acting against dies *F* and *G*. Spring pad *Q* is thus depressed, but elevates the work flush with the surface of the dies when the punches ascend. Two pilot pins *V* locate the strip by entering the perforated holes at the ends of the work.

At the next station, the first and second forming operations take place. In these operations, the four wings *A*, Fig. 97, are bent up by punch *K* when it enters the forming die *M* against spring pad *L*, and the two perforated ears at the ends of the blank are bent down. When the pad comes in contact with the bottom of the die, the first two forming operations are completed. Upon the ascent of the punches, the spring pads again elevate the work flush with the surface of the dies.

The next station is idle, except that the work is guided through it toward the final operation by the length of the spring pad *N*, which is fitted for an easy sliding fit between the two previously formed ears. When the punches ascend, three spring pads act to elevate the work flush with the surface of the dies.


WORK MATERIAL
G
F
H
U
U
SPLIT
SPLIT
SEVER

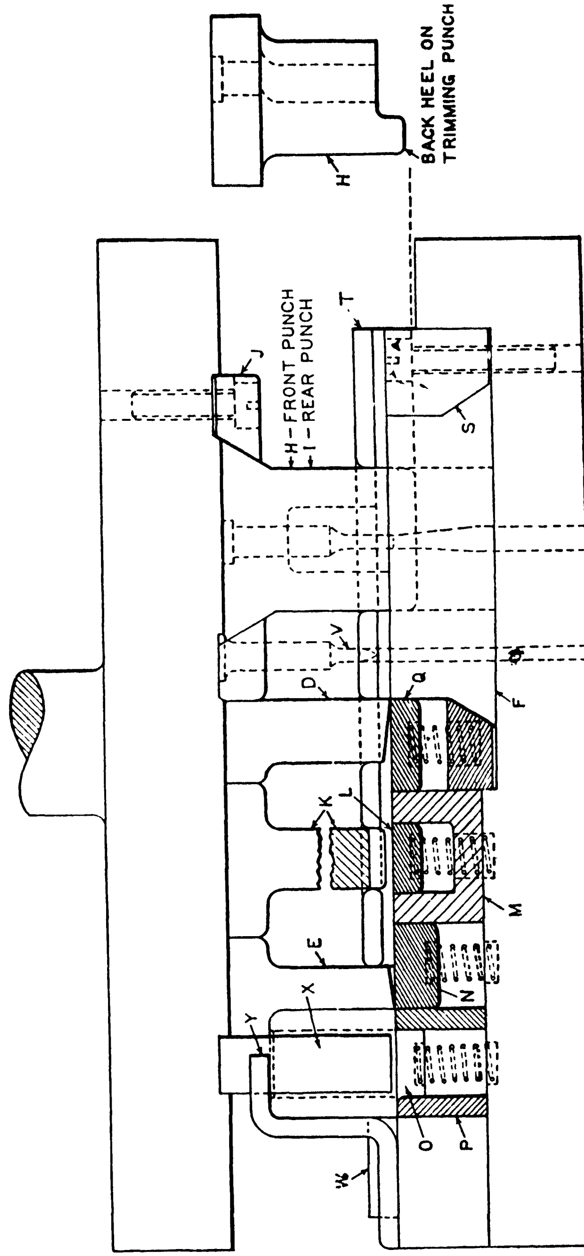


FIG. 98.—Progressive die that can be adjusted to produce four different sizes of frames, which are shown in the upper views of Fig. 97.

In the final operation, the forward end of the work registers against the positive stop *W*. The work is now located over the opening in the forming die *P*. Inside this die is a strong spring pad *O*, which holds the face of the work flat while forming and subsequently causes the work to follow the forming punch *X*.

When the punches again descend upon the work, the piece to be formed is severed from the strip by punch *E*, which is a trifle longer than forming punch *X*. The forming punch is already in contact with the blank and holds it positively by its continued descent against the spring pad. This results in pushing the severed work down into the forming die and bending up the two wings shown at *B* in the lower view of Fig. 97 and the frame sides *C* shown in the upper view. In the next ascent of the press ram, the work, now completed, follows the punch, as previously stated, and is carried into contact with two positive hooks *Y*, which strip it off the punch.

The Press.—This work is done in a No. 4 inclined press, and, after the last forming punch is withdrawn, the completed parts are free to slide from the die into a container behind the press. All the spring pads are now flush with the die surfaces, and the tool is ready to finish the pieces rapidly. The press runs at a speed of 80 strokes per minute, the hourly output being about 3,000 pieces. The press is foot-tripped for each piece.

Fabricating Machine-gun-belt Links.—Figure 99 shows a cut-and-carry progressive die set up in a Dieing machine. This equipment completes one .50-caliber machine-gun-belt link at each stroke of the press, or 140 pieces per minute. The machine is provided with an automatic double-roll feed having a special drive that feeds the strip during 120 deg. of crank stroke. This feature permits the use of a shorter stroke than could otherwise be adopted.

An adjustable "scrap cutter" is mounted at the end of the die. An electric limit switch is arranged to stop the machine automatically 45 deg. from the maximum downstroke; this is in case the strip is over- or underfed when the pilots cannot register properly.

This machine is also adapted to fabricate .30-caliber machine-gun-belt links of the Colt types, the Vickers .303, and any other foreign links of similar shapes and sizes. The finished pieces are delivered through a discharge chute shown at the right. However, in practice, most manufacturers arrange these machines in a straight line. There are two belt conveyers running along the left-hand end of the machines in a direction parallel to the crankshaft. The discharge chute and scrap cutter are so arranged that the completed links drop on a conveyer belt leading toward the annealing furnace, while the scrap

travels in the opposite direction, on the other belt, to the scrap loading platform.

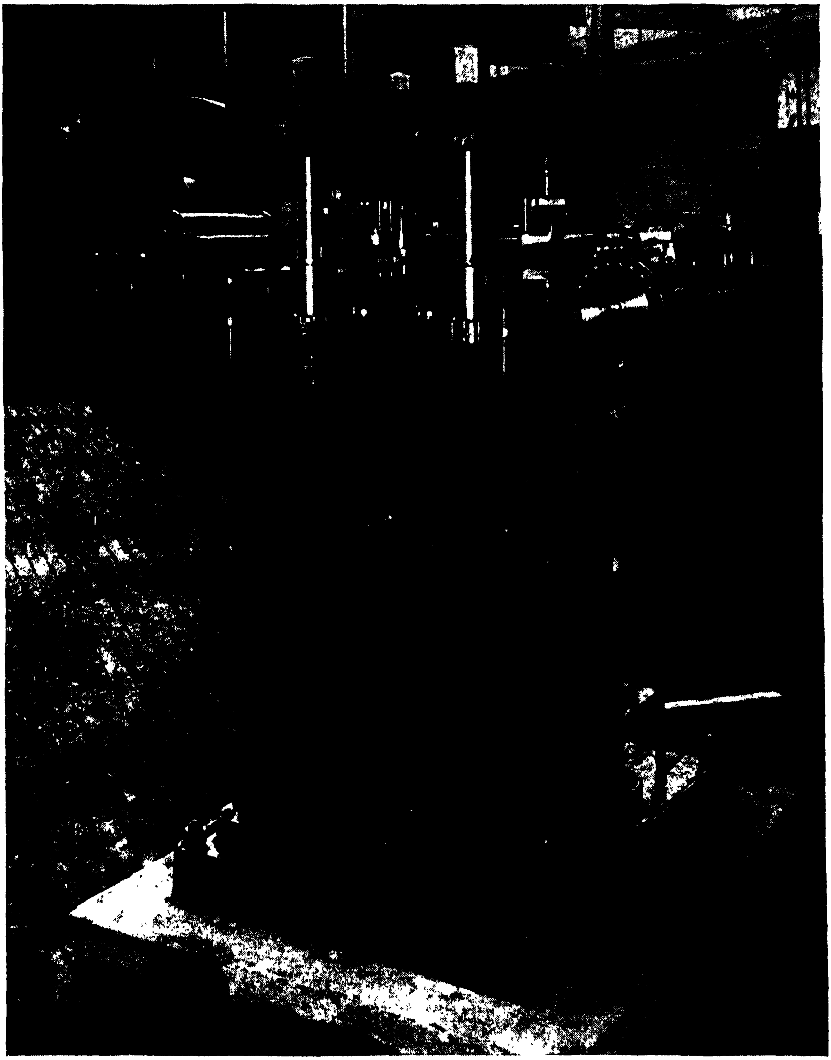


FIG. 99.—Front view of a 60-ton Dieing machine equipped with a cut-and-carry progressive die. (*Courtesy of The Henry & Wright Mfg. Co.*)

Fabricating Machine-gun-belt Links and Cartridge Clips.—Figure 100 is a close-up front view of the cut-and-carry progressive die in the Dieing machine shown in Fig. 99. This die is composed of seven active stations. It is used for shearing, curling, forming, and ejecting .50-

caliber machine-gun-belt links, similar to the one illustrated in Fig. 101. The output runs as high as 140 completed parts per minute. Accuracy of the product can be held to 0.0002 in., if necessary.

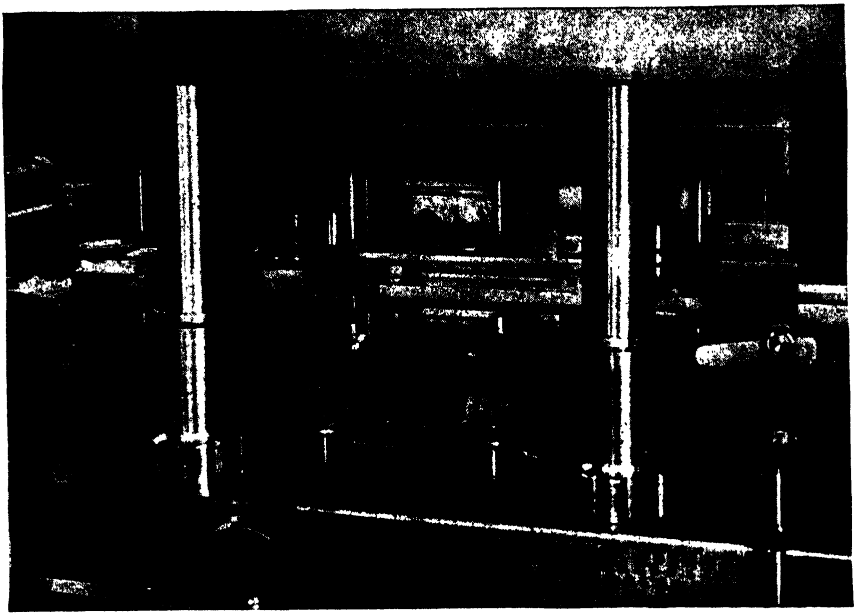


FIG. 100.—Close-up front view of the cut-and-carry progressive die shown in the Dieing machine, Fig. 99. (*Courtesy of The Henry & Wright Mfg. Co.*)

The two final forming stations in this die are equipped with sliding arbors which are brought into position after the feed is stopped, so that the forming or curling operation can be done by striking "metal to metal." On the upstroke of the machine, before the feed begins, these arbors are automatically withdrawn. This feature, of using double striking arbors, accounts for the superior results that belt-link manufacturers obtain when producing gun belt links in these types of progressive dies, as compared with the older single-operation method in which there was only one forming operation over arbors.

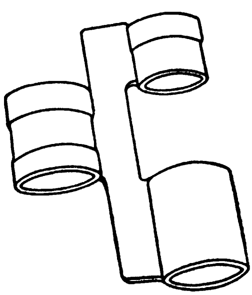


FIG. 101.—Machine-gun-belt link produced complete, one per press stroke, 140 per minute.

In Figs. 102 and 103 are other products that contribute toward winning the war. Here we have a different type of gun belt-link, and a cartridge clip for Vickers .303-caliber rifles. Both these pieces are products of cut-and-carry progressive dies.

In laying out progressive dies, several important dimensions of the press in which the die will be used must be considered. A list of these dimensions follows.*

A. Shut height.

B. Roll feed height.

C. Shank diameter and length.

D. Opening in press bed (width and length).

E. Length of crank stroke.

F. Does ram ascend within the ways?

G. If *F* is yes, check the opening between ways to clear punch holder.

H. In which direction should the strip be fed into the die?

I. Tonnage of the press.

J. Additional holes for clamping punch holder to ram.

K. Bolt hole centers in the press bolster plate.

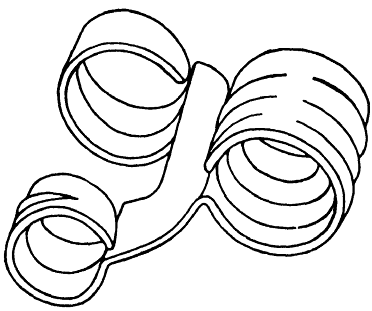


Fig. 102.—Another sample of the numerous machine-gun-belt links produced, one at each press stroke, complete and to precision limits from flat strip materials.

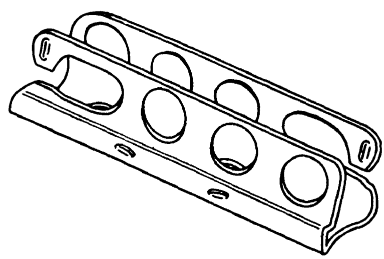


Fig. 103.—Cartridge clip for caliber .303 rifle produced complete, one per press stroke, 120 per minute.

High-precision Progressive Dies.—Plate I is a reproduced photograph of a high-grade progressive die showing the "skeleton" and a blank of the work. The work is part of a timing device used in antiaircraft maneuvers. The high precision required in this piece of work compares favorably with that found in the movement plates of high-grade watches and clocks, the only difference being that this work is larger. The limit tolerances are about the same. This calls our attention to the astonishing accuracy, even for mass production, that is possible to attain in using well-designed and carefully constructed progressive dies.

The principal operations done in this 10-station die are: pierce, trim, flatten, shave all holes and the outside diameter of the part.

* Moore Special Tool Co., Inc.

The work material is known as Lancashire brass, 0.157 in. gage. This is a "high-leaded" brass and harder than "full hard." It is a homogeneous material and is an alloy that "stays put." This alloy is a Scoville product developed many years ago and has been long in use for important parts of accurate timepieces.

Operation of the Die.—The stripper plate shows two slots underneath at its right end; these are used for finger stops. In production, the strip is halted for operations by a notched stop in the opposite guides under the stripper plate. These notches contact two shoulders shown near the right end of the skeleton strip. When starting in a new strip, the operator engages the first finger stop and then "trips" the press, next the second finger stop, and from then on he advances the strip against the notched stop. A notched stop of this type is sometimes called a "French stop."

Precision Limits.—The smallest hole pierced is 0.114 in. diameter, and shaved to 0.124 in. diameter. Tolerance in hole diameters is: plus 0.0005 in. minus 0.0000 in.; tolerance between hole centers: minus 0.0005 in. plus 0.0000 in Blank must be flat within 0.003 in. Two elongated slots are pierced and shaved twice. All holes in the die and the four stripper inserts are ground to compensate for heat-treating distortion. Needless to say, all holes must be held in location within about 0.0002 in. to ensure that the product will be within the specified limits.

All the rules of good diemaking practice must be strictly adhered to in a high-grade die of this character. Holes in the stripper plate are lapped after grinding to make them resistant to wear. All piercing and shaving punches are lapped to limits of plus 0.0001 and minus 0.0000 in., and are fitted in their respective guide holes within about 0.0001-in. clearance.

Construction.—The elongated slots are filed through the punch plate and the plate is left soft. However, through the stripper, these slots are filed, "stoned," and lapped. The die blocks are divided to make convenient the open grinding of these slots so that they will maintain their sizes throughout the thickness of the die.

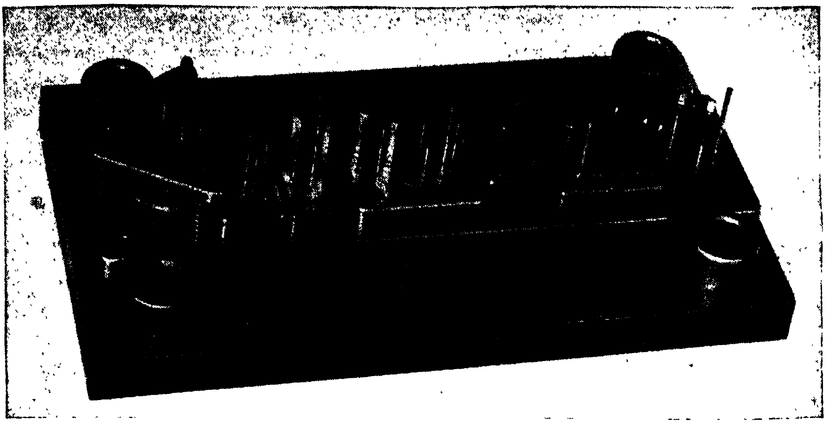
All round holes in the die are "bushed" with thin-walled bushings, hardened, ground, and lapped. All the holes in the die and stripper plate are ground on a Moore Jig Grinding Machine and then lapped for sizes and finish. Notice the four hardened inserts at the left end of the stripper plate. These are made of solid blocks, are precision guides for the punches, and are "screwed and doweled" within openings in the stripper plate.

Two "rough and ready" pilot pins straddle between the blanks, after which two or more round finishing pilots enter holes at each station of the work. The rough pilots being longer, they do most of the work in "yanking" up the strip when the punches ascend. When the finishing pilots enter the work, they reposition the strip by moving it only about 0.002 in.

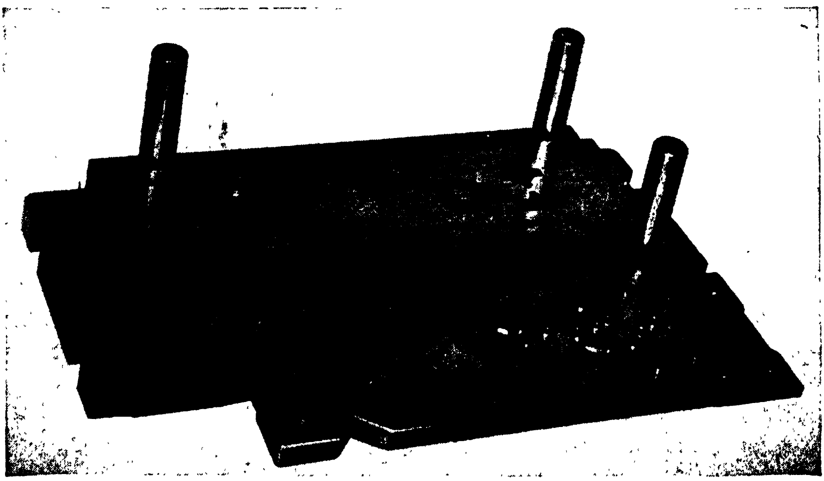
Single-station die operations similar to these have been done for many years in several watch- and clock-manufacturing plants, but this tool is probably the first one in which such high-precision work has been done in mass production and progressively. Several of these tools have been made, and all of them are considered successful. However, they verge toward becoming a "headache" because the punches are so small, compared with the thickness of stock. This tool has made runs of over 100,000 parts per grind, but 50,000 parts per grind is about the average.

Shallow Forming and Drawing.—Shallow forming, and especially shallow drawing, operations are performed progressively on the surface of the die blocks in a conventional type of die. The punches are attached on the punch holder and aligned over the dies; the dies are worked out in blocks attached on the die shoe. Drawing depths do not usually exceed $\frac{3}{16}$ in. and the diameters are two or three times the drawing depth, or more. Compression spring shedders are fitted into each opening of the drawing dies. At the maximum descent of the punches, the shedders "bank" on the die shoe and "spank" the work to size and shape. On the upstroke the work is ejected by the shedders and is then advanced into the stations ahead for additional operations either in the bottom of the cup, around its flange, or both.

Deep Drawing of Light Gage Shells.—Deep shells, such as those used for grid caps in radio tubes and for pencil tips, are produced progressively in compound inverted punches and dies. The dies are attached on the punch holder and aligned over the punches, the latter being attached on the die shoe. The punches are surrounded by spring stripper plates and the dies are fitted with compression spring shedders. This type of progressive die provides a flat side on the strip under the work that permits the strip to ride across the stripper plates and punches, flush with the surfaces of the plates. The drawing of shells above $\frac{3}{16}$ in. high could not be done successfully in conventional dies, in which the drawing dies are mounted on the shoe.



Punches and punch holder.



Die and stripper.

Skeleton and scrap strip.

PLATE I.—A high-precision ten-station progressive die. (*Courtesy of Moore Special Tool Co., Inc.*)

CHAPTER VI

LAYING OUT DIES IN CONSECUTIVE ORDER

Simplicity of Die Engineering.—One important fact we learned in Chap. V, in designing "cut-and-carry" progressive dies, is that when we design a series of die operations to be performed in the same tool, the consecutive order of operations must be studied carefully. They must follow one another in a practical mechanical order. If this is not done, the completed tool either will be a complete failure, or it will produce imperfect work and thus continue to be a source of trouble until the die is "torn down," "reworked," and made right.

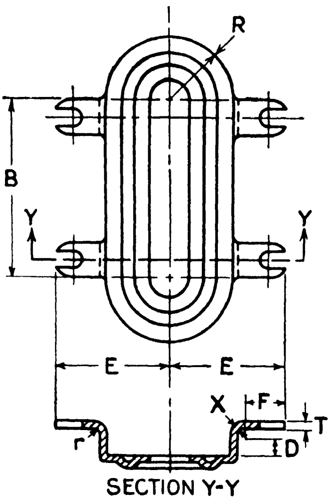


Fig. 104.—Mild-steel bracket for which a stamping and blanking die is required.

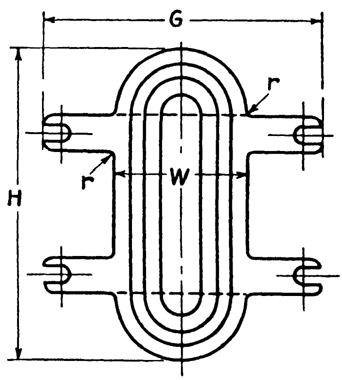


Fig. 105.—The blank development.

Die engineering, like all other work, is not so difficult if it is begun right and then followed through step by step, with the design and proper locations of all the parts of a die that naturally follow one another in consecutive order. The following systematic procedure shows how this can be done.

Blank Development.—Consider the formed bracket shown in the two views in Fig. 104. It has an elongated hole cut through its center, and around the hole is a stamped stiffening rib or "bead," for strength-

ening the body of the work. The first obvious step toward designing a blanking die for this piece is to develop the blank. The standard formula for the developed length of right-angled bends is $D + X + F$, in which X is the length of arc r, taken on the neutral bending line at $T/3$ from inside the bend, or $X = (T/3 + r)\ 1.5708$, and $F = E$ minus $(R + T + r)$. Hence the extreme developed width G of this blank is $2(R + D + X + F)$; the width of the blank body is $W = 2R$; and length H is $B + 2R$, as seen in Fig. 105.

Scrap-strip Development.—The next step is to lay out the scrap strip, Fig. 106. This is done with three cardboard templates of the blank. The templates are arranged along a horizontal line, and

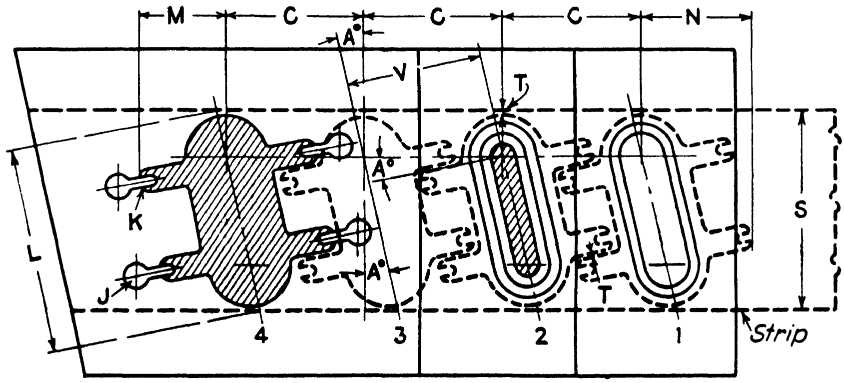


FIG. 106.—Layout of the scrap strip and die blocks.

several different positional layouts are tried for material economy until the most economical one is found. This is determined, in each of the trials, by comparing the different areas that one blank occupies in the strip; it is the least product of C times S that gives the greatest economy. Spaces T are allowed between the cuts and between the ends of the blank and outer edges of the strip. For light-gage materials, under about No. 22 gage, $2T$ is used, and, for very thin materials, more than this allowance is frequently necessary.

Scrap-strip layouts can easily be checked mathematically by using the lettering assigned in Fig. 106. By construction, angles A are equal. $\cos A = V/C$ or S/L. Hence $V/C = S/L$, and

$$(C \times S) = (V \times L).$$

$C = (V \times L)/S$. $V = (C \times S)/L$, and $L = (C \times S)/V$.

Pounds of Stock Required per 1,000 Blanks.—Pounds of stock material required per 1,000 blanks are $C \times S \times P \times 7.3$, in which P is the material weight per square foot, and 7.3 a constant that includes

5 per cent for waste ends. If blanks are in multiple rows, use C divided by the multiple.

Press Exertion Required.—The necessary pressure, in tons, for cutting mild steel is the sum, in inches, of the lengths of the entire cut perimeters in stations 2 and 4, multiplied by the thickness of strip in inches, times 25. To this must be added the pressure required for stamping the rib in station 1. This pressure can be determined by a "tryout" in a hydraulic press which has a pressure gage giving the tons. Otherwise this stamping pressure must be estimated. If the compressive strength of the material is 60,000 lb. per square inch, and this operation is "spanked" at the extreme downstroke of the ram, as it should be, the press exertion here will be about 30 tons.

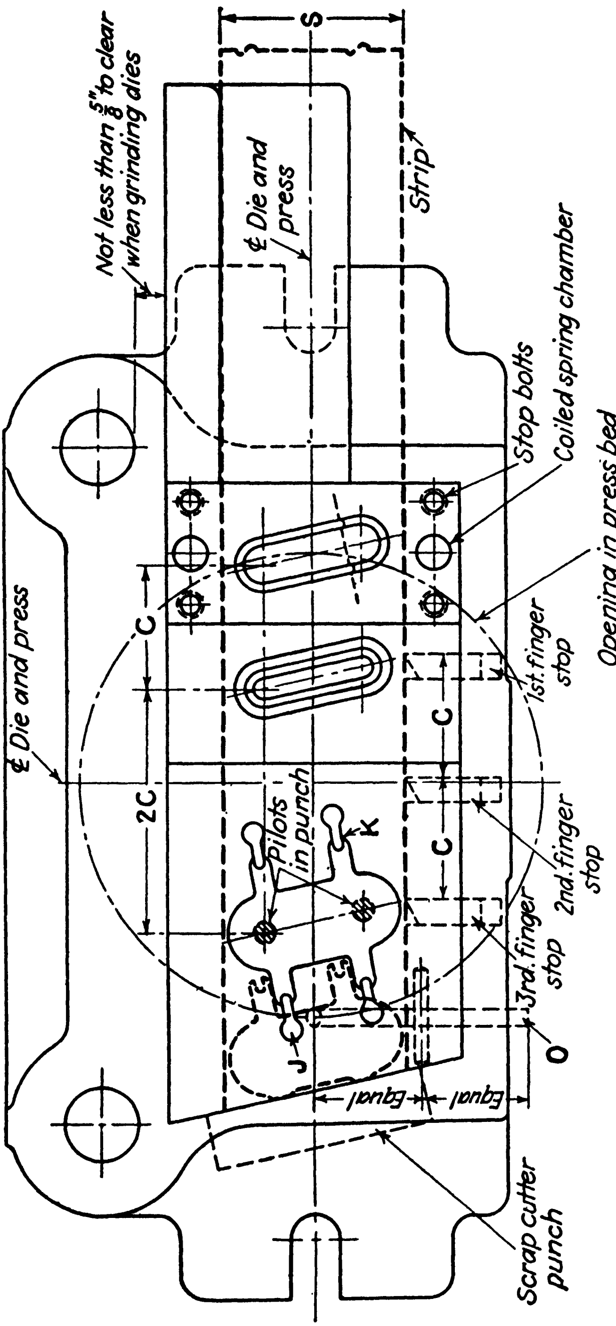
Stripping Pressure.—The stripping pressure, or the pull in tons under the stripper plate, when the ram ascends with the punches cut into the strip, will be the sum, in inches, of the lengths of the entire cut perimeters in stations 2 and 4, multiplied by the thickness of strip, in inches, times 1.75. The number of full blanks contained in a strip 8 ft. long (96 in.) is computed as follows:

$$\frac{96 \text{ in.} - (M + N)}{C} + 1$$

The Die Blocks.—The die-block sizes and positions are sketched across the scrap strip in Fig. 106. This is a sectional die. It comprises three blocks for ease in construction, hardening, and replacements. Block No. 2 is "end-milled" around the die opening. Thus a "land" remains around the elongated hole which is easy to grind. This construction also permits the stamped rib to surround the "land" at this station, so that the strip itself lies flat on the die for perforating the hole, as shown in the end view of this block in the front elevation of the assembled die, Fig. 107.

Die blocks must be large enough to include screws for fastening them, and dowel pins to ensure their fixed positions. As a rule, the minimum space at any point in the die opening, to the outside edge of the block, is from one to one and a half times the thickness of the block.

In the blanking-die block, No. 4, are seen four die inserts J. These inserts help to avoid a lot of trouble in the upkeep of the die. This die would be impractical to build and use without these inserts. If these projections were made as a solid part of the block, there would be eight sharp corners K to be worked out through the die. Moreover, when one of the solid projections became broken it would be necessary to anneal and rework the whole block. On the other hand, a broken insert can readily be replaced with a new one.


S
Not less than 5/8" to clear when grinding dies
℄ Die and press
Strip
Coiled spring chamber
Stop bolts
Opening in press bed
℄ Die and press
C
C
2C
C
1st. finger stop
2nd. finger stop
3rd. finger stop
Pilots in punch
K
J
O
Equal
Equal
Scrap cutter punch

PLAN OF DIE

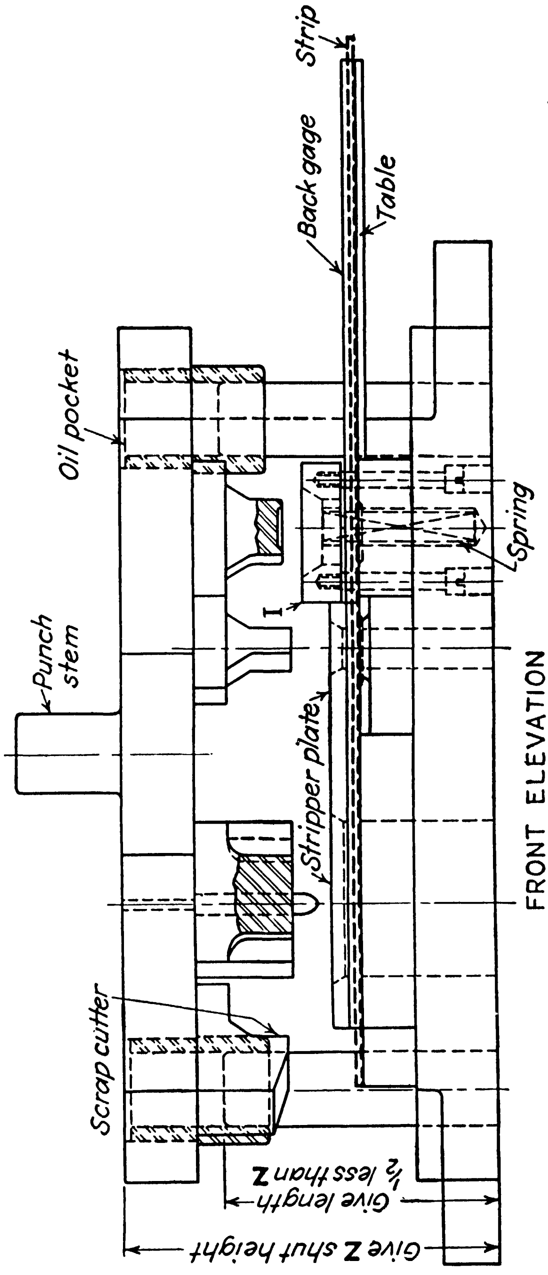


FIG. 107.—The assembled die for progressively stamping, spanking, perforating, blanking, and cutting off the scrap frame.

After the scrap-strip and die sections have been correctly worked out, the drawing, Fig. 106, is placed under a larger sheet and traced through for making an assembly drawing of the die. This procedure saves much time. All that now remains to be done is to draw a suitable die shoe around the blocks, and to project the front elevation of the assembled die below the plan.

The Assembled Die.—For large dies having considerable spread between stations, it is always best to dot in the outline of the opening through the bed of the press as it appears under the bolster plate. This will show whether or not all the scrap slugs and the blank itself can pass through freely and fall beneath the press. Sometimes the punch stem must be relocated in order to provide a changed position of the die for the proper disposition of all the scrap slugs and blanks through the press-bed opening. In such cases, the punch stem is threaded and screwed into a tapped hole in the punch holder and then welded in place. In the assembled die, Fig. 107, the opening through the press bed is shown in the plan by the dot and dashed circle. Tool-engineering offices should have the necessary dimensional data of all their company's power presses. This should include the sizes and shapes of openings through the press beds.

Operation of the Die.—At station 1, the forward end of the strip is entered under "spanker pad" *I*, and then against the first depressed finger stop. When the punches descend, the rib is stamped and "spanked." Spanking is done simultaneously with forming the rib, by contact between the punch flange and pad *I*. Notice that the two cutting punches are longer than the stamping punch. This ensures that perforating and blanking are finished before stamping. The stamping station must be first; otherwise the perforated hole would be distorted when the rib is drawn and formed. Stamping draws the metal "locally" and does not exert any horizontal "pull" on the other punches.

In station 2, the strip is halted against the second depressed finger stop. The stamped rib fits loosely over the land around the elongated die opening. Next, the punches descend and the elongated hole is cut, and after they ascend, the strip is advanced against the third depressed finger stop. This station is idle, in order to provide sufficient die area for assembling the inserts *J*. About one-third of a blank is cut here, but enough area of the strip lies over the die to avoid punch deflection. After the punches ascend, the strip is again advanced with its cut edge registered against automatic stop *O*. The strip is now ready to be advanced ahead into regular production. Two pilot pins, in the face of the blanking punch, engage in the ends of the elongated slot and register the strip before blanking.

Jig-boring the Die Block.—Figure 108 illustrates the standard design for a jig-boring layout. The die block is clamped down on the table of a jig-boring machine, in a position that coincides with angle A, in Fig. 106. This idea saves the designer much time, as it avoids computing the "straight" dimensions from triangles. In the position shown, all the straight dimensions can be taken directly from the blank development in Fig. 105, to which the distances from the edges of the block can be added. Only the indicated dimensions are given. The remaining dimensions are simply duplicates of these, because this is a symmetrical piece of work.

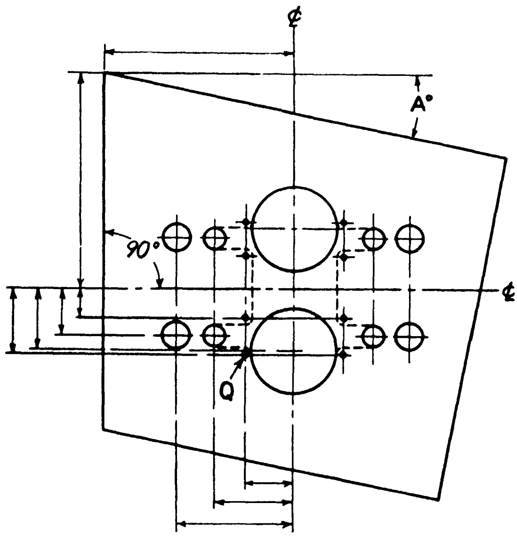


Fig. 108.—A jig-boring layout for the blanking-die block.

Eight holes, $\frac{1}{8}$ in. deep, one of which is shown at Q, are drilled $\frac{1}{16}$ in. diameter, and used for inserting filing buttons. Tool-steel hardened and ground buttons are made with $\frac{1}{16}$-in.-diameter shanks and body diameters with radii equal to r, in Fig. 105. The buttons are inserted in the $\frac{1}{16}$-in.-diameter holes, and then used as a template for filing around the radii. After jig-boring, the contour of blank is scribed on the block between holes, and the die opening is sawed out on a band saw. The opening is sawed undersize. It is then finished (leaving grinding allowance) on a die-filing machine, set at an angle for die clearance. When the block is returned from the hardener, it is checked for shrinkage on the jig-boring machine and then ground inside and outside to the desired sizes.

At the extreme left end of the die, a scrap cutting punch is attached to shear off the scrap frame as it passes out of the die. The cut is

made along the left edge of the blanking-die block. The pieces are cut into "blanking center" lengths, and then fall away from the die into a chute leading into a barrel. This is a good way to dispose of long unwieldy lengths of scrap strips.

IN SEPARATE DIES FOR THE SAME PIECE THE CONSECUTIVE ORDER OF OPERATIONS MUST ALSO BE CAREFULLY STUDIED

The Three Following Dies Involve Cutting Off and Drawing, Piercing and Corner Notching, Forming Down Four Flanges

Cutting Off and Drawing.—Referring to Fig. 109, the cover *A* is made from 1/32-in.-deep drawing steel. In the first operation, the strip is fed from front to back against the stop pins *B* and between pins *C*, being guided by the strip gage *D*. The tools for this and the succeeding operations are built in reverse of the conventional order, the punch being below and the die above. This construction permits the use of the positive knockout pad *F* operated by a vertical rod, the upper end of which contacts a crossbar on the upstroke of the ram and thus ejects the finished work.

When the ram descends, a blank is cut off by the shearing edges at *H*, the blank having an area allowance on all four sides for subsequent trimming operations. As the ram continues to descend, the die *J* draws the blank over the punch *K*. At the end of the stroke, the small radii are completed and the flange is "spanked" down on the spring pad to iron out the slight drawing wrinkles. On the upstroke of the ram, the work is carried up with the die, because the spring pad follows it up, and is ejected by the knockout pad referred to above.

Piercing and Trimming.—The tool for the second operation is illustrated in Fig. 110. For this operation, the knockout pad *A* is recessed to clear the drawn body on the work and bears directly on the flat flange, ejecting the work without distorting it. The work is placed on the trimming punch *B* and is accurately located by the pilot *C*. When the ram descends, the edges of the flange are trimmed and the four corners are notched.

The face of die *D*, for this operation, is ground 1/2 deg. from the horizontal on all four edges to give a shearing cut. In addition to trimming, two 1/4-in. holes are pierced in the flange by the punches *F*. Four chisel scrap cutters are located in the die shoe, and around the punch, to cut the rectangular frame of scrap into four pieces for easy removal. On the upstroke of the ram the work, having been sheared into the die, is carried up within it until the upstroke is nearly completed, at which time it is ejected by the positive knockout pad *A*.

Forming Down the Flanges.—The final operation consists in folding down the four sides of the flange without drawing the metal, as drawing would cause distortion in the work. This operation is

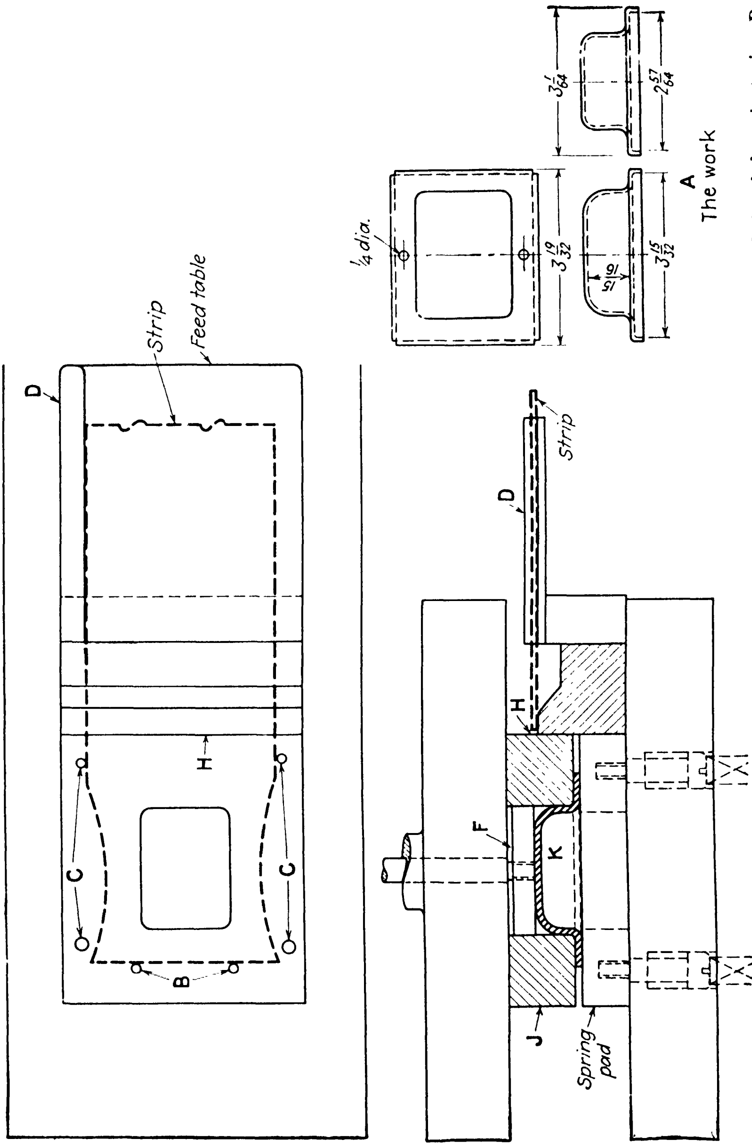


FIG. 109.—The blank is cut from the strip at *H*, the cover is then drawn in this die, the strip being fed against pins *B* and guided by gage *D* on the feeding table.

performed by the tool illustrated in Fig. 111. The design of this tool is similar to that of the tool for the preceding operation and it functions practically the same as for the second operation, excepting that the edges of the flange are formed down instead of being trimmed.

The presses in which each of these three tools is used are inclined and the ejected pieces of work fall to the rear of the machine and into a receptacle provided for them.

Justifying Tool Costs.—A study of this subject helps one to decide how much time and money to spend in building tools for producing a

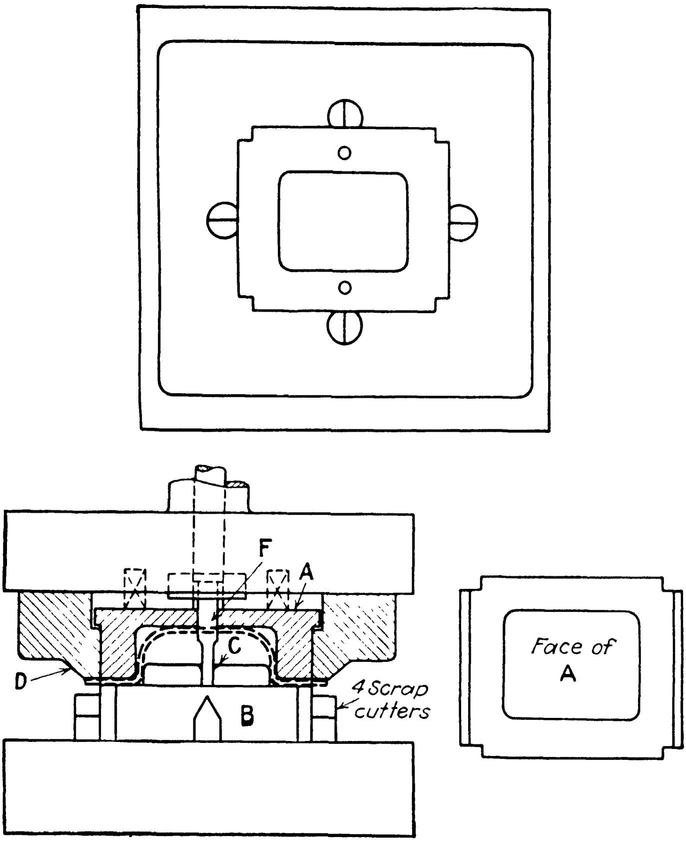


FIG. 110.—The drawn cover is trimmed and notched and two holes are pierced. The scrap is cut into four pieces for easy removal.

few or many parts or whether tools are really necessary for making only a few parts. This is determined by comparing the cost of doing a job by hand in the toolroom with the cost of building necessary tools plus the cost of using them to do the job in some other department.

If \$100 is spent for tools, labor, material, and overhead to produce 100 pieces of work, it is evident that the unit cost is \$1. If the output is 200 pieces, the unit cost is 50 cents, but for 10,000 pieces the cost is only 1 cent each. Therefore, if the output is practically unlimited,

the cost of the most expensive tools and equipment can be easily absorbed.

Low-production Manufacturing.—Some plants maintain a semimanufacturing department in the charge of a foreman who takes pride in being a very resourceful mechanic. Beside his regular work, he finds time to design, build, and use such temporary tools as are neces-

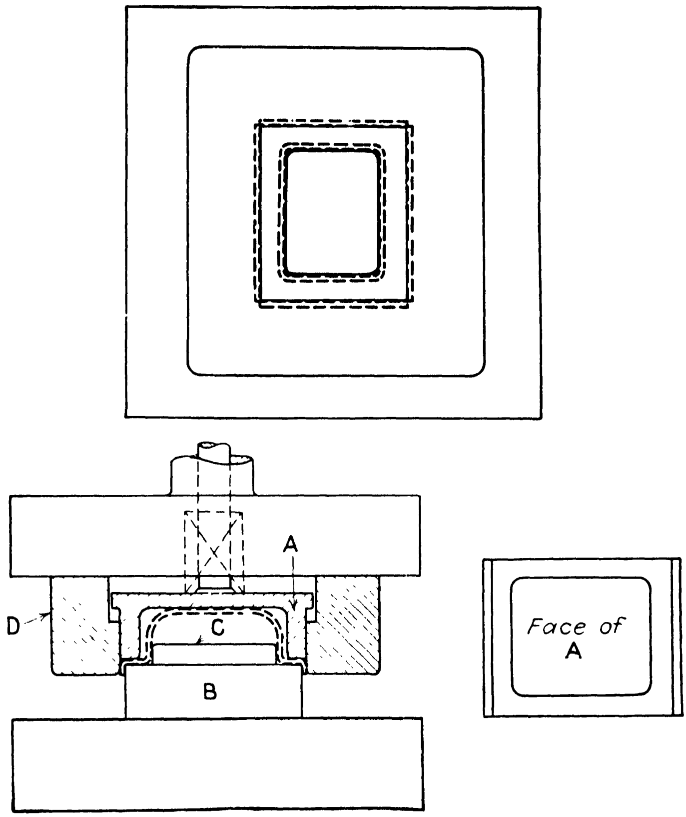


FIG. 111.—The four edges of the flanged cover are folded down, the notched corners preventing a drawing action and consequent distortion.

sary for producing small-lot orders. This department relieves the toolroom, where manufacturing should never be done anyway, of much burdensome work. Some very ingenious tool designs and manufacturing methods have been developed in semimanufacturing departments. There are cases where they have run small-lot orders for years with temporary tools. These cases occurred during the evolutionary days of telephones, typewriters, phonographs, radios, and automobiles. The same conditions are present in today's production of many types of experimental parts used for war purposes.

Cost of Work Produced in Dies.—If M represents the material cost per 1,000 pieces, then M = area of the material used for one blank $\times$ 7.3 $\times$ weight of the material per square foot $\times$ cost of the material per pound. This formula allows 5 per cent for waste ends and miscuts. The area of material used for one blank is found by multiplying the width of the strip in inches by the blanking center distance in inches.

The following formulas are used for computing the labor and material costs per 1,000 blanks:
For hand feed:

$$T = \frac{S}{0.024N} + M.$$

For roll feed:

$$T = \frac{S}{0.048N} + M.$$

In these formulas T is the total cost of labor and material per 1,000 blanks, S the operator's hourly wage including overhead, and N the number of press strokes per minute.

For bending, drawing, and forming operations, the cost of production can be closely approximated by using a stop watch and going through the motions involved in the operation. Someone holds the stop watch and is ready to stop it instantly. When all is in readiness, the operator picks up an imaginary blank and goes through the motions of placing it in the die, pressing the clutch treadle, and removing the finished piece from the die. These hypothetical operations should be repeated several times, and the average time noted. From these data the labor cost per 1,000 pieces can be closely found for all types of presswork.

CHAPTER VII

PERFORATING AND PIERCING

Difference between Perforating and Piercing.—Generally speaking, dies that punch holes through sheet metals and other materials are called "perforating dies" when the punch diameters are several times larger than the work thickness or of different shapes than round. They are known as "piercing dies" when the punched holes are very small. A single tool may have both of these conditions.

Alignment of Punch and Die Members.—The first requirement in designing good perforating and piercing dies is to know that the punch holder and die shoe are as nearly perfectly aligned as possible. Each individual punch and die must also be symmetrically aligned. Good alignment in dies depends upon the size and number of guideposts used. Four substantial guideposts should be used in press tools designed for perforating and piercing a large number of holes.

Punch and die clearances are necessarily small in all piercing dies because the work sheet is relatively thin. Unless the punching members are rigidly aligned, punch deflections may occur just before the punch points enter the dies, and cutting edges will be chipped.

Punch Clearances.—*The punch governs the size of pierced holes, while the die governs the size of cut blanks.* This rule indicates that, for piercing, the punch must be made the exact size of the required hole, and clearance must be *added* in the die around the punch, while in blanking just the reverse is true, that is, the die is made the exact size of the blank, and the required clearance is *subtracted* from around the punch. However, for very accurate piercing, the over-all size of the punch is *increased* 0.002 in. over the size desired, and that of the blank is *decreased* 0.002 in. below the size wanted, because the work expands approximately this amount after the operation has been completed.

The general rule for over-all punch clearance is based on a percentage of the blank thickness. It is 5 per cent of the thickness for brass and soft steel, 6 per cent for medium hard-rolled steel, and 7 per cent for extra hard steel. If T is the sheet thickness, punch clearances are then $T/20$, $T/16$, and $T/14$, respectively. These divisors are constants that give 5, 6, and 7 per cent of the sheet thick-

nesses. Half of the over-all punch clearance is equally spaced all around between the punch and die edges.

Die Clearances.—Die clearance is angle *F* seen in Fig. 113, and is usually $\frac{1}{4}$ deg. on each side of the die, or $\frac{1}{2}$ deg. included angle.

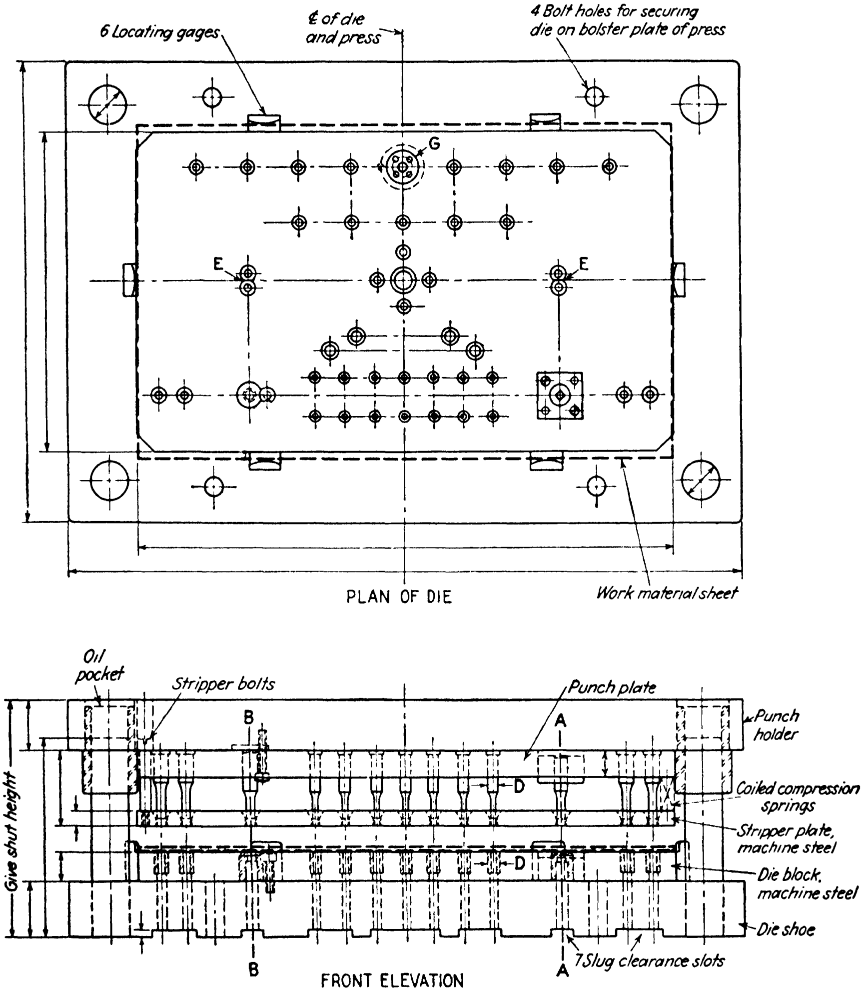


FIG. 112.—Layout for a large perforating and piercing die. Several problems usually encountered in designing such dies are illustrated here, and the solution of them is revealed in the text.

The object is to clear the edges of the cut slugs as the punch, in descent, pushes them through the die. Dies are usually filed straight about $\frac{3}{16}$ in. down from the top surface of the block, before clearance begins. Piercing and perforating punches used for cutting materials $\frac{3}{32}$ in.

thick or more usually have a slight side relief of about 1/16 in. taper per foot. Side clearance in punches facilitates stripping, but it is impractical to use unless the punch points are more than 1/8 in. in diameter. It has the fault of reducing the punch diameters slightly after the punch faces are ground.

Perforating Die Assembled.—Figure 112 shows the design and drafting technique used in presenting drawings of large perforating

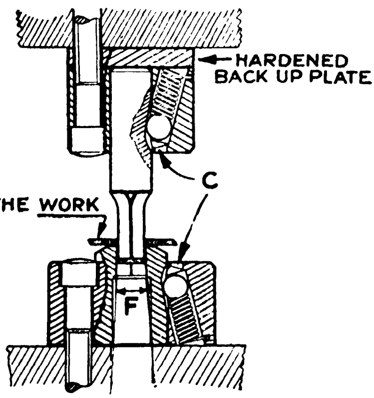


FIG. 113.—Section through vertical plane *A-A* in Fig. 112, showing the Richard Brothers' patented method for locking or removing individual punches and dies. Both the punch and the die are locked in a holder by the thrust of a compression spring behind a steel ball. Either the punch or the die can be unlocked and then removed by depressing the ball with a small rod that can be inserted through holes *C*. Broken members can then be replaced or different sizes and shapes of punches and dies substituted, without removing the main die from the press.

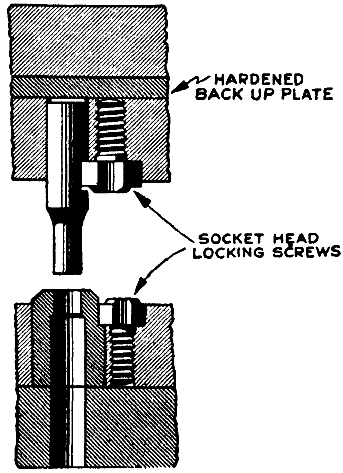


FIG. 114.—Section through vertical plane *B-B* in Fig. 112, showing the Hovis method for locking or removing interchangeable punches and dies. Each punch or die is locked under the shoulder of a socket-head screw, as shown. The punches and dies can be removed by backing up the locking screw a quarter turn. Broken members can then be replaced, or other sizes and shapes of punches and dies substituted, without removing the main die from the press. A jig is used for locating the correct position of the punch, relative to the die, after a button die has been mounted on the shoe.

dies. This die punches 51 holes through the work sheet, which is shown positioned between six locating gages in the plan view.

All the die holes are "bushed" with high-speed steel hardened and ground bushings, so that bushings can be exchanged for other sizes. This makes it possible to use a machinery-steel die block, and avoids all the hardening difficulties encountered when using a solid block of tool steel. Large blocks are divided into conveniently shaped sections. At *E* is shown the method of "flatting" bushings against one another where the distance between hole centers is less than the diameters of the bushings.

Another important feature is the equal diameters of the punch bodies and the outside diameters of their corresponding die bushings. This is shown at *D*, and the purpose is to provide for clamping the punch plate and die block flat together, on the table of the jig-boring machine, which facilitates boring equal diameters of holes in both plates simultaneously, a procedure that saves much time.

Five die holes are contained in one bushing at *G*. These holes are too near together to be "bushed" separately. Bushings of these types are "shouldered" into a counterbored hole underneath the die block and are prevented from turning by inserting dowel pins. The dimensions for jig boring are given from the vertical and horizontal center lines, both ways to each of the hole centers.

Seven slots for clearing slugs are cut across the bottom of the die shoe. Punched-out slugs fall through the dies into these slots, where they rest on the surface of a solid bolster plate. The slugs are removed at intervals with a hand tool or are blown out by directing a jet of compressed air into the slots from the mouth of a nozzle.

Removable Punches and Dies.—Figures 113 and 114 are sectional views, taken in Fig. 112 through planes *A-A* and *B-B*. These show individual "setups" of certain removable punches and dies, and both are commercial equipment. However, this equipment can also be incorporated where center distances are too close for individual retainers. This is accomplished by using a special retainer plate or plates, which are furnished for including a large number of punches and dies in any one or more of the plates.

Removable punches and dies are convenient for two reasons. (1) Chipped and broken members can be quickly removed and replaced with new ones. (2) Members can be removed and other sizes and shapes substituted. Such changes can be made without taking large heavy dies from the press and carting them to the toolroom. Hence, a minimum of time and expense is involved in such emergencies.

Rubber Strippers.—The operating details of these strippers are shown in Fig. 115. Knowing the required pressure to "strip" the punch, all that is necessary is to order from the manufacturer the rubber stripping unit of sufficient strength to do the work. It is best to add a safety factor of 50 per cent to the pressure determined by the following formula.

$$P = 3{,}500 \times L \times T$$

where P = pressure required for stripping, in pounds.
L = length of cut edge, in inches.
T = thickness of material.

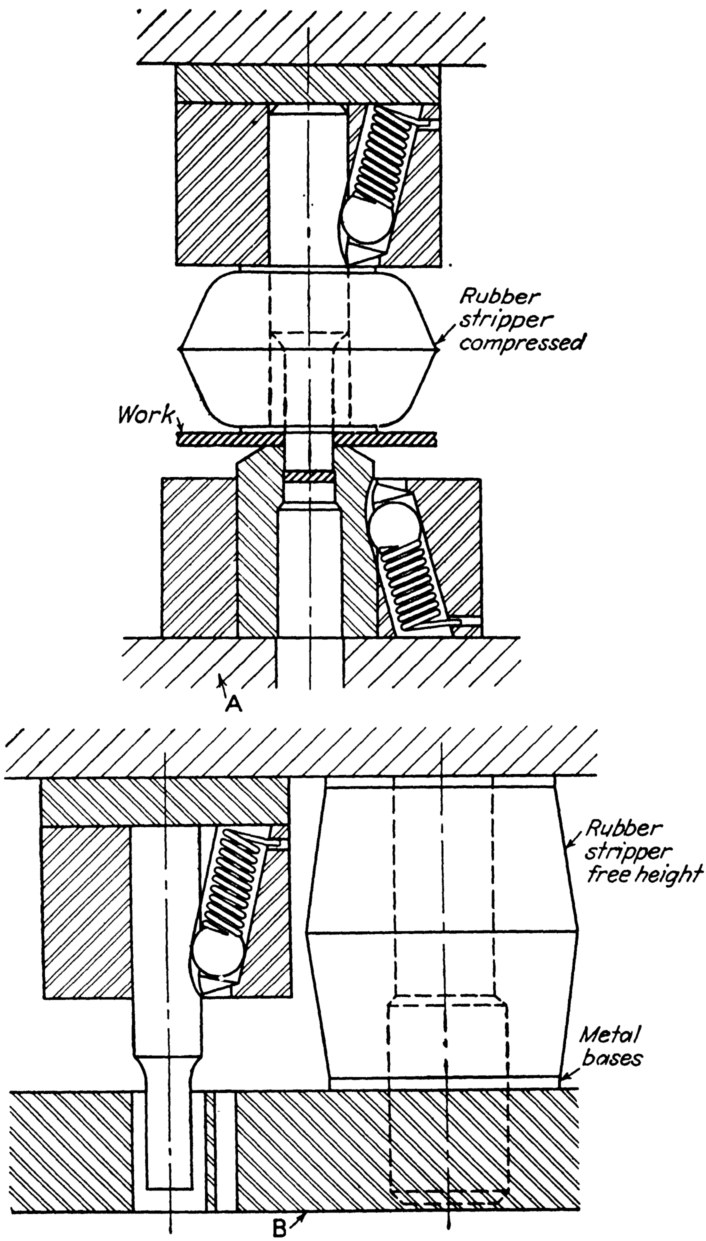


FIG. 115.—Rubber stripper shown at *A* eliminates the installing of a costly stripper plate, the mounting of shoulder screws and springs, and the drilling, counterboring, and tapping of holes or the drilling of pockets for coiled springs. At *B*, rubber strippers are mounted where the die-set thickness is not sufficient to permit the drilling of spring pockets or, between punch holder and stripper plates, where a low-shut height of the die is required. (*Courtesy of Richard Brothers, Division of Allied Products Corporation.*)

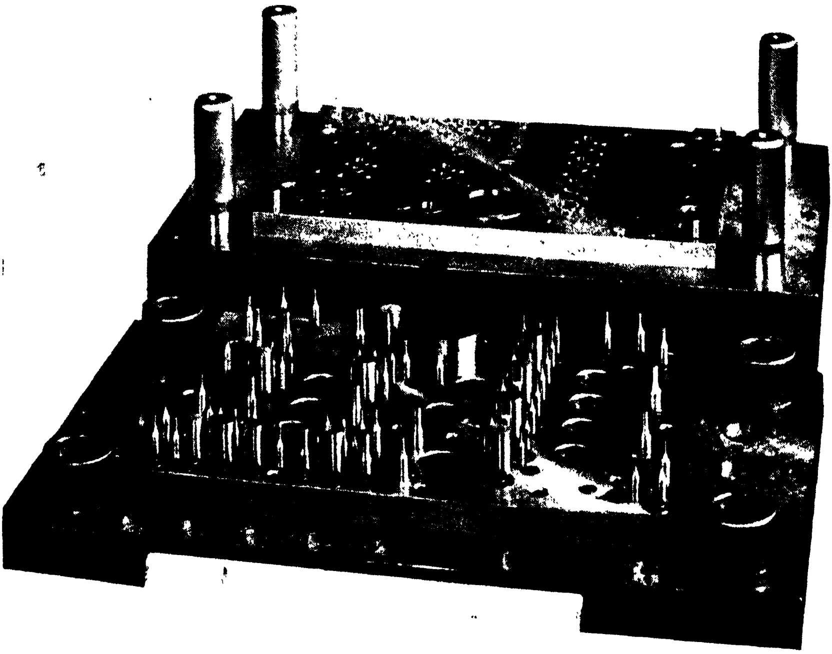


FIG. 116.

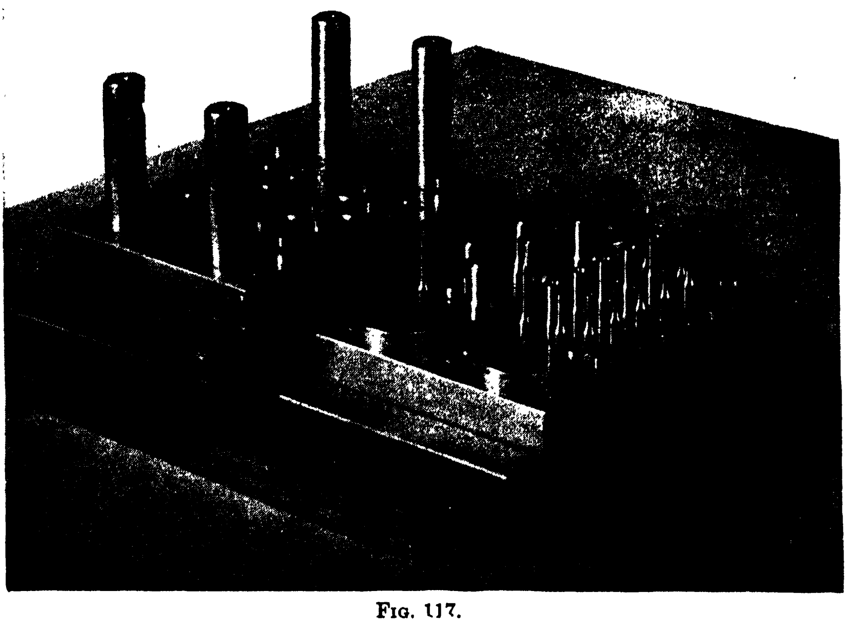


FIG. 117.

Figures 116 and 117 are photographic cuts which are excellent views of large perforating and piercing dies. The die in Fig. 116 punches 83 holes in an aluminum front panel used for British and American bomber-plane radio sets. Figure 117 shows a die that punches 17 holes

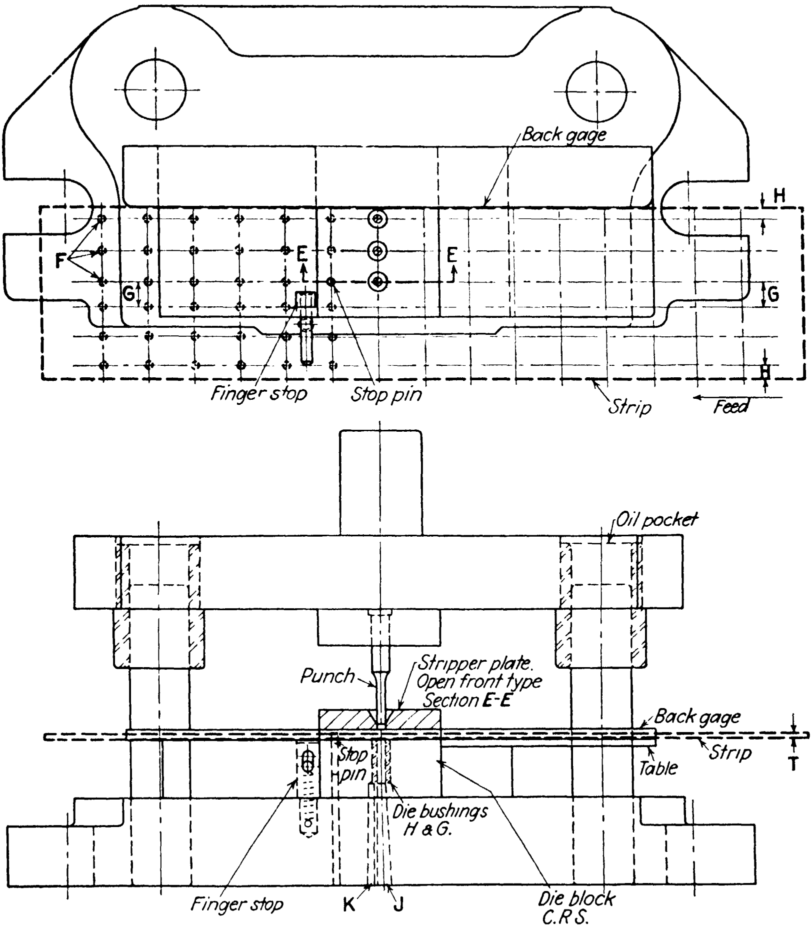


FIG. 118.—Low-priced perforating punch and die for the production of small orders.

in paper stock which is only 0.004 in. thick. In order to do this successfully each of the punches must have only 0.0004 in. over-all clearance in the die holes. Any tool engineer or diemaker will appreciate the outstanding accuracy required to accomplish these results and to "line up" the punches and dies perfectly.

The die holes in both of these tools are "bushed" with thin-walled hardened bushings, and the stripper plates have been removed to

show the bushings. The punches and dies are locked in position by the Hovis screw lock, and both these photographs were furnished by the courtesy of that company.

Output Governs the Tool Design.—The probable yearly requirements of the part to be produced must be carefully considered before press tools can be intelligently designed. This is especially true of perforating and piercing dies. If the tool is for piercing only 100 parts, each containing 50 holes, a cheap tool that punches one hole per press stroke can be designed, or for 500 parts a tool that may cost twice as much, that punches three holes at a time. But for 25,000 parts annually, a tool that costs perhaps 50 times more would be necessary, and it must be designed for perforating all the 50 holes in one press stroke.

Perforating Three Holes per Stroke.—The perforating die illustrated in Fig. 118 takes care of work in which 150 panels or strips are perforated with 90 holes each. The order is expected to be repeated only about two or three times annually. This is clearly a case where a cheap tool is necessary.

The strip is started in the die with its upper edge against the back gage and its forward end in contact with the finger stop. The finger stop is lifted and thus stops the strip; a tension spring restores it to its normal position, after punching the first station of holes. The first three holes at *F* are punched while the strip end is registered against the finger stop. The remaining 14 stations of three holes each can then be punched rapidly in consecutive order. The panel is then turned over, with its lower edge in contact with the back gage, and the above cycle is repeated.

It requires 30 press strokes to complete one panel. However, if the width of strip varies from its given dimension, the variation will appear in dimension *G*. This variation cannot be eliminated by any type of die possible to design. It will "show up" either at *G* or on one edge of the strip at *H*, unless an expensive strip centralizer is designed and attached on the die. This addition would defeat the construction of a low-cost tool. But if the centralizer did its work perfectly, the variation would still appear divided equally between the two edges at dimensions *H*. A hand feed and pin stop, which function as follows, are used in this die.

Hand Feed and Pin Stop.—This is the simplest method known for stopping a strip through the stations of a die by hand. For feeding the strip from right to left, a positive stop pin is driven into a vertical hole in the face of the die block. The right edge of the stop pin is located from the right edge of the die contour, at a distance equal to

the length between cutting stations and parallel with the direction of feed.

The height of the pin is about 1½ times the stock thickness. The pin is placed well below the horizontal center line of the work to facilitate raising the front edge of the strip when passing the punched hole over the top of the pin. Registering the right edge in the punched hole against the pin exposes a new portion of the strip for punching the next hole.

Tapering Outlet Holes for Slugs.—At *J* the slug clearance hole is tapered all the way up to the die bushing opening. The standard for this taper is ¼ deg. on each side, or ½ deg. included angle. This feature prevents the slugs from crowding together and finally clogging the hole. If the slug clearance hole is made straight, and it usually is, small slugs will interlock and jam across the diameter of the outlet hole. Slugs often jam so tightly in straight outlet holes that it is necessary to drill them out to open the hole. Hole *K* is a clearance for knocking out the die bushing if necessary to make replacements.

New Ideas May Lead to Errors.—In applying new ideas it is well to avoid *overusing* them. For example, it was once thought that since automobile transportation was so speedy and reliable it must be equally good in any contingency. But for "short hauls" and frequent stops, it was soon learned that horse-drawn vehicles were better and more economical. With this pardonable digression from the subject of dies, attention is directed toward its applications. Some astonishing parallels are revealed by making comparisons. When high-speed steels appeared 40 years ago, management thought that uses for carbon tool steels were on their way out. Today, there are more uses for carbon tool steels than ever before. Again, expensive installations of air and hydraulic cylinders for most high-production operations are excellent. However, these installations sometimes fail to pay out even in high-production jobs because the initial investment is too high. In one instance, 12 hydraulic punching units, with quick-action compressed-air returns, were horizontally arranged around a circle for perforating a dozen equally spaced holes through the periphery wall of a shallow-drawn shell. When these were replaced with a side-cam die equipped with punching units, "set up" in an ordinary power press, the side-cam die produced just as good work, and in shorter time, than the hydraulic fixture that cost ten times as much.

Side-cam Die for Horizontal Punchings.—In the side-cam die seen in Fig. 119, six equally spaced holes are perforated through the wall of the drawn and trimmed shell *B*. Punching units *C* can be removed and rearranged in this, or other, tools for doing similar punching

operations. Each unit is provided with its corresponding side cam, which operates the slides carrying the punches. The die bushings and punches can be exchanged for other sizes or removed for replacements.

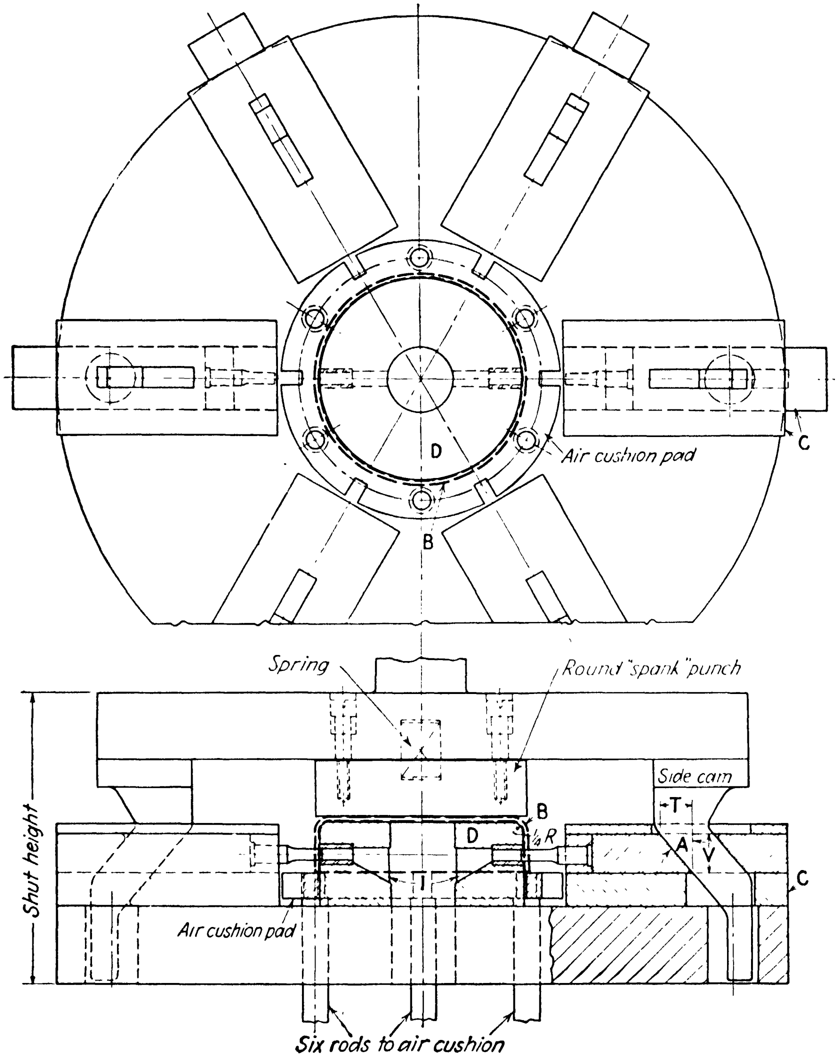


FIG. 119.—Semiuniversal punching units arranged in a circle for perforating six holes horizontally in a side-cam type of die. The die bushings are "shimmed out" for grinding. No guideposts are required in the die set for this type of press tool.

In fact, these punching units are semiuniversal and can be adapted in several other types of press-tool piercing dies.

When the ram is up, the face of the air cushion pad is ¼ in. under flush with the top surface of stud *D*. The shell to be perforated is

placed "mouth down" on the pad and around the stud. The shell is a sliding fit over the stud. The ram, in descent, carries the "spanking" punch into contact with the shell bottom, and continuing to descend, depresses the shell and pad against the air cushion. While the ram descends, the side cams gradually advance the six horizontal punches, and complete the punching operations at the maximum downstroke. If the shell wall is thick enough, no "stripping" of the punches is necessary. When stripping is necessary for thin stock, the slides are designed sufficiently large to include light stripping plates and springs behind them, or rubber strippers may be used as shown in Fig. 115.

The cut slugs fall away through slots *I* and drop out beneath the die shoe. A slanting chute attached under the bolster plate delivers the slugs away from the air cushion, which is attached directly under the press.

Horizontal Travel for Cam Slides.—The best angle for operating horizontal slides actuated by side cams is 35 deg. (See angle *A* in Fig. 119.) Let T = travel of the horizontal slide, and V = vertical descent of the side cam. Then, $T = \tan A \times V$, and $V = T/\tan A$. When A is 35 deg., $T = 0.7 \times V$, and $V = T/0.7$. However, 35 deg. cannot always be used for angle A. There are conditions where the press stroke is too short in proportion to the required slide travel, and a greater angle than 35 deg. must be adopted.

Using "Horn Dies."—In a horn die the operation is performed in front of the press ram and bolster plate. This provides more vertical space for handling excessively high pieces of work. Horn dies are necessary when the size of work or its formed-up sides are too high to be included within the maximum shut height of the press. These difficulties are encountered in forming large circular or U-shaped pieces, assembling odd shapes of parts, or when perforating vertical holes around the peripheries of large diameter shells. The die set is special and extends out in front of the press ram and bolster plate as shown in Fig. 120. In this design the punch holder can also be offset higher by using a notch and thus extending it up in front of the ram, gaining more die space if necessary.

Perforating Circular Shell Walls Cheaply.—The horn die illustrated in Fig. 120 has only one perforating punch and die bushing, yet it can be arranged to punch any number of equally spaced holes in the wall of a circular shell. It can punch from 2 to 20 holes or more, depending upon the diameter of the shell. The success of this die is due largely to the correct design of an automatic stop. It uses an end-thrust type of stop.

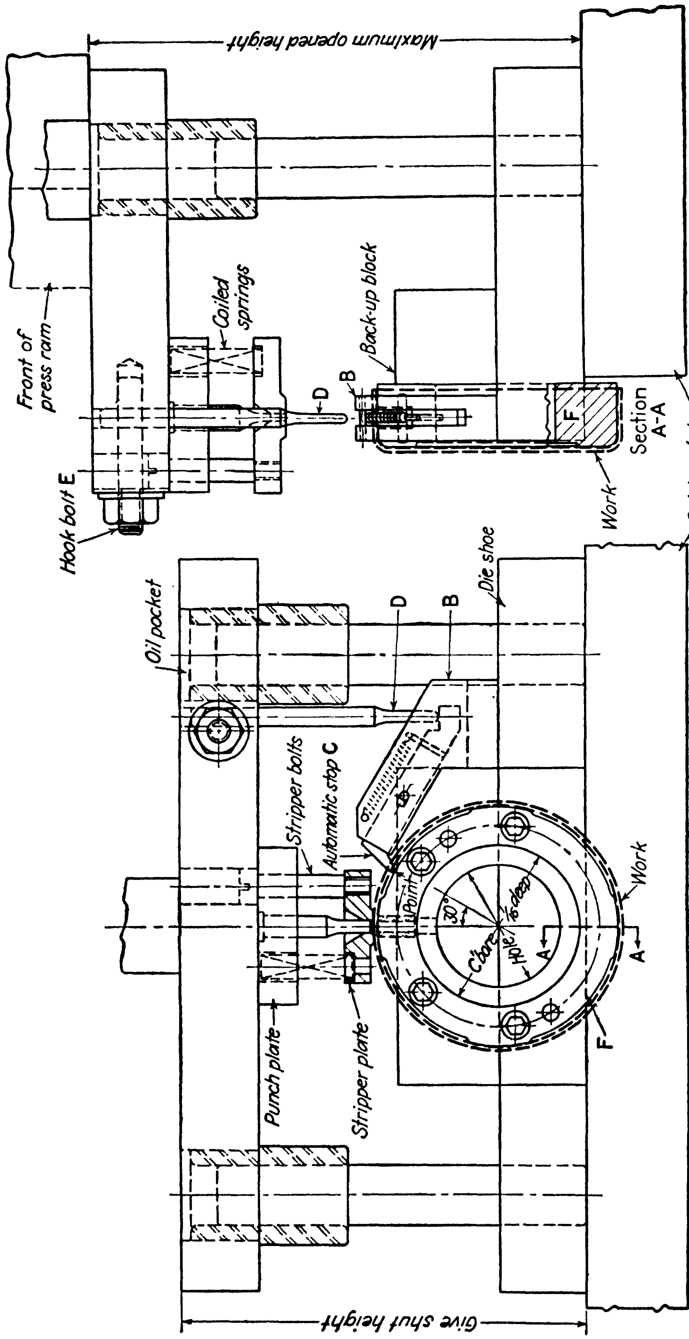


FIG. 120.—Low-cost die that perforates 12 equally spaced holes through the side wall of a previously drawn cup. This is a "horn type" of die.

End-thrust Automatic Stop.—This design of automatic stop is one of the best. It can also be mounted in a positive channel stripper plate over any kind of blanking or cutting die. Its simple design lends itself particularly well in the place where it is used, Fig. 120. There are many practical applications for this stop, and it should be considered first whenever automatic stops are needed.

This stop is composed of only four parts and a nut and washer. Body *B* is positively attached on the die shoe; it is also slotted, and in the slot stop lever *C* is mounted on a fulcrum pin that slides in a

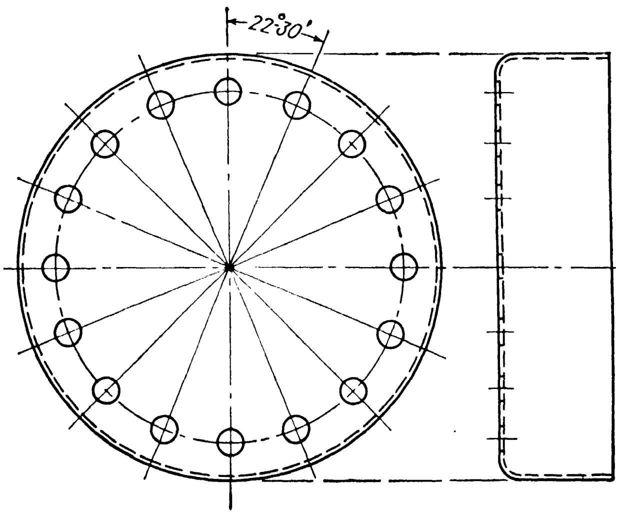


Fig. 121.—Sixteen equally spaced holes in the bottom of a drawn shell that can be punched in a cheap die similar to the one shown in the preceding figure.

short elongated hole in *B*, as shown. Stop lever *C* is an easy fit within the body slot. Finger *D* can be adjusted vertically and then locked at a suitable height by tightening the nut on hook bolt *E*. When the punch descends and punches a hole, finger *D* contacts the right end of *C* and elevates the point on the stop out of a hole in the work where it was just engaged. A light coiled spring then pulls the stop toward the left, and when the finger ascends, the point on the stop comes down on the surface of the shell wall. The operator then turns the shell clockwise, and the stop engages and registers in the last hole just cut. This operation is repeated until all the 12 holes are perforated.

The shell is an easy working fit on stud *F*. The stud is relieved by four equal scallops to facilitate turning the shell. A relieved stud of this sort reduces friction when revolving the work, and clears grit, chips, and dirt. If it is thought necessary, a spring plunger pad can

be mounted in a swinging gate across the shell and arranged to keep the work constantly registered against the face of stud.

Perforating Circular Shell Bottoms Cheaply.—Figure 121 shows a shell having equally spaced holes perforated on a circle around its bottom. This job can also be performed in a die similar to the one in Fig. 120. In this case, stud *F* is secured flat down on the die shoe, and the automatic stop functions as just described, except that the movement of the stop lever must be so designed that its right end can be depressed by the operator to permit the shell to enter over stud *F*.

It is understood, of course, that the jobs performed in Figs. 120 and 121 are for small orders, say up to about 300 parts per "setup." For high outputs, all the holes would be punched in one press stroke, as illustrated and described under Fig. 119.

CHAPTER VIII

METHODS OF FEEDING

Circular Dial Feeds.—There are many practical applications for dial-fed dies. The operations include redrawing, piercing, notching, light broaching, embossing, assembling, wiring, bending, forming, and many other die operations. This feed is also employed in multiple operations where riveting, press fitting, folding, and seaming together of two or more parts are done simultaneously.

Dial feeds can be designed semiautomatic or fully automatic by attaching the necessary chutes, hoppers, and magazines through which shells or other work parts may be delivered into the passing stations on the dial and then carried around into the die for desired operations. However, this equipment is too expensive to build unless the annual output of work is very high. Dial feeds for small parts are usually run on single-crank gap-frame presses. The presses may be inclined if necessary to deliver the finished work behind the machine.

Circular Dials in War-plane Work.—There are cases in which large dials, or more properly speaking, "rotary tables," several feet in diameter are mounted in hydraulic presses, and a half dozen operators work at places around the dial. The operators feed parts into the stations on the dial as it revolves. A photograph showing this kind of work being done is reproduced in Plate II, page 199. This equipment is used in assembling bomber parts. The parts made are interchangeable assemblies of units for war-plane production in the Lockheed plant, at Burbank, Calif.

Operation of Dials.—In loading ordinary dials, the workpieces are placed in duplicate stations attached around the face edge of the dial; the stations are then "indexed" (revolved) with the dial and halted in rotation under the punch for die operations. Work removal is done at stations on beyond the die, by using vertical ejector pins operated from underneath the dial, and sometimes by using a "flip-off" finger over the dial.* At other times it is possible to eject certain shapes of work through an open "nest" in the dial, by the descent of a vertical punch finger. The dial and work are indexed beyond the die,

* A flip-off finger, which is sometimes called a "pick-off arm," is illustrated in Figs. 132 and 133.

one or two stations, and over a clearance hole through the die shoe. The finger in descent is now in vertical alignment with the work, the nest, and the clearance hole, and at the downstroke the work is pushed out where it is free to fall beneath the press. This is a simple design for ejecting work from dials, but it is effective and can be used if working conditions permit.

Locking the Dial.—A positive locking device is necessary for halting the work station of the dial directly under the punch. This may be accomplished in several ways. One method is to attach a pilot pin in the punch holder with a compression spring behind it. The pilot pin is vertical and has a "bullet-nosed" point. The pilot in descent slips into a bell-mouthed hole in a shouldered bushing driven in the dial—there is one bushing for each station—and locks the dial in correct position. If the indexing mechanism "goes wrong," and the pilot, in descent, misses the bushing hole, the spring then allows the pilot to depress, and no damage occurs in the tool. The pilot is a sliding fit through a press-fitted guide bushing in the punch holder.

Hand-fed Dials.—When using this type of dial a serious difficulty arises. The operator may fail to revolve the dial properly in positioning the next station. He then engages the clutch and the ram descends, but the punch comes down in the wrong place, it wrecks the dial and the tool itself and perhaps fractures the press frame. To avoid such accidents, the clutch must be operated either by a mechanical control or by a limit switch used in conjunction with the movement of the dial. This control is placed at the circumference of the dial and, in timed contact with suitable cams or "trips," prevents engaging the clutch unless the dial station is correctly positioned under the punch.

Pilot Pin Relocates Dial.—Hand-fed dials are locked in operating positions by descent of a vertical pilot pin with a compression spring behind it. The point on the pilot is considerably ahead of the punch point for the die. The pilot nose slips into a 1-in.-diameter hole in a bell-mouthed shouldered bushing which is positively located in the dial. The position of each station is controlled by its one bushing. The pilot pin has a bullet-nosed point which will relocate the dial and work before the punch descends, even though the operator may have carelessly revolved the dial station ½ in. either way from its correct position. The success of this idea means that the circle diameter for the bushings must be small enough to space them so closely together that the bell-mouthed openings in the shoulders of the bushings can be blended over into those of the next bushing. This can be done and still leave ½ in. neck of metal between the bushing bodies in the dial.

This description applies only to a cheap hand-fed dial and to moderately low productions of work. Dials used for high-production work are automatically revolved and indexed by an attachment driven from the left end of the press crankshaft.

SWAGING COPPER BANDS ON 20-MM. SHELLS

Dial Feeds.—A surprising variety of presswork can be performed on revolving dials in which multiple stations are equally spaced on a circle. Its numberless tooling designs and its many applications in the pressworking of metals are possibilities that await only the inventive ingenuity and versatility of the designer.

There are three very good reasons why dial-feed presses will take a prominent place in the production of many pieces and partial assemblies that will be used for small parts in war equipment. First, these tools are rapid producers because they operate semiautomatically. Second, they are ideal tools for women operators because the parts to be fabricated are light and easy to handle. Third, revolving dials are "safety-first" tools, because all the feeding is done in front of the press and as far away as possible from the danger zone under the press ram.

Indexing the Dial.—Several methods are employed for advancing the dial one station at each press stroke and simultaneously locking the dial just before the actual operation begins. In one case, an attached chain at the rear of the punch holder passes down under an idle pulley and then forward to where it is secured on a spring-actuated lever arm under the dial. One end of the lever arm carries a pawl that engages in equally spaced notches cut in the perimeter of the dial for driving, while at the opposite end of the arm is the locking mechanism. The die, dial, and feed are thus self-contained, and for this reason it is probably the easiest and cheapest design to make.

In general, dials are fed from left to right, or counterclockwise, but they are sometimes made to revolve in the opposite direction. It depends upon which side of the press is best suited for the ejection and delivery of the finished work. Feeding the dial can be made to occur during either the up- or the downstroke of the press. However, for most work the dial is revolved and locked in position during the first 90-deg. turn of the press crank, and necessarily before the pilots or punches contact the die. This being so, it naturally follows that the designer must select a press having sufficient die space and crank stroke to perform the proposed operation safely, and he should know the actual press stroke in inches. It will be found at times that the interval between locking the dial and beginning the operation is a

very narrow margin. For computation of the ram descent, see Fig. 364.

The Work.—The assembly of a copper band on a 20-mm. steel shell is shown in Fig. 122. The diameter A of this shell, in English measurement, is approximately $^{25}/_{32}$ in. The copper band, or ring, is shown swaged into a groove which has been cut around the shell. The copper ring, before swaging, is seen at B and is an easy fit over A.

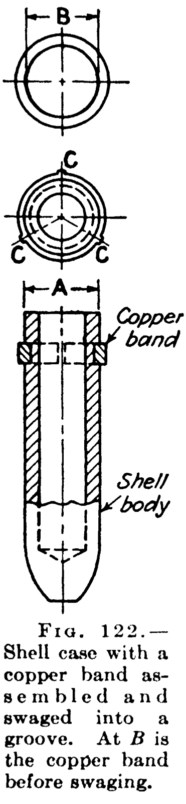


Fig. 122.—Shell case with a copper band assembled and swaged into a groove. At B is the copper band before swaging.

In swaging, or squeezing the ring into the groove, there are three points C where the copper is allowed to overflow. The overflow compensates for possible variations in the sizes of the parts. After the assembling operation, these extrusions are shaved off in another die.

The Die.—Figure 123 illustrates the general design of a dial-feed press tool that is used for swaging the band around the shell. The dial carries 12 stations, and the swaging station is seen at D. Figure 124 is a "close-up" cross-sectional view cut through a vertical plane at the center of station D. This view also includes the punch above the station and is shown in its position at the downstroke of the press. The assembled work is also shown here in heavy dotted lines. In Fig. 125 are the details of the three equal conical sectors that comprise the squeezing members of the punch.

When the punch is at the top of its stroke, a coiled compression spring in the punch stem has depressed the conical sectors, and the hole in the center of the punch is wide open. The diameter of this opening is $^1/_{16}$ in. greater than the outside diameter of the copper ring. Two operators feed the passing stations in the dial. One places the shells into the center hole of the stations, grooves up, and the "bullet-nosed" end of the shell rests on the face of the die shoe with the cut groove flush with the top surface of the stations, but exposed to take the rings. The other operator places the copper rings over the protruding ends of the shells and flat down on the station surfaces.

Each of the loaded stations is stopped under the punch at D. When the punch descends and contacts the station surface, the conical sectors become depressed and close together; the copper ring is then squeezed into the groove. At two stations beyond D, the finished piece is ejected from the dial. A punch, not shown, enters the hole

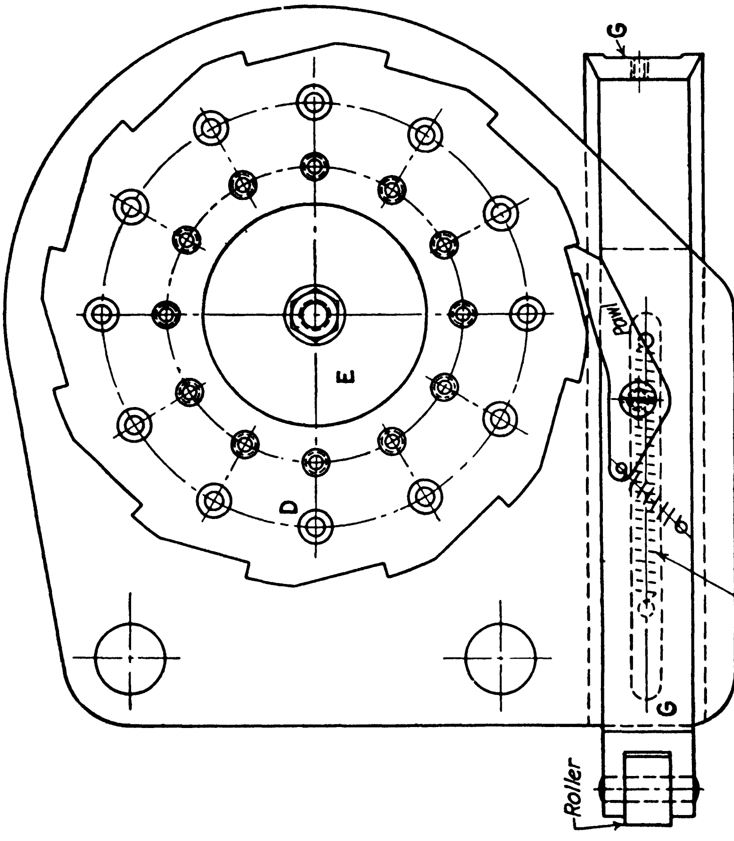
in the center of the shell; the end of this punch carries an expanded split ball which has been hardened and spring tempered. The ball engages by friction within the shells and, in ascent, lifts them out of the dial and into contact with a positive "sky hook" or finger that "strips" off the shell. The work falls into a chute that leads into a "tote pan" at the rear of the press.

The press tool assembly in Fig. 123 is shown in its closed position. Disk *E* has a fiber plate between itself and the dial. The disk is held down by bolt *F*, which has a spring washer under its head. The purpose of this arrangement is to retard the forward movement of the dial and thus prevent its being overfed by the thrust of the pawl. Pawl slide *G*, with a roller at its left end, is in constant spring tension contact with a cam which is driven by a sprocket chain in connection with the crankshaft. The tension spring is seen at *H*. When the punch descends, a pilot pin enters one of the 12 bushings shown in the face of the dial; the pilot locks the dial firmly before the punch contacts the station. This action occurs after the first quarter turn of the press crank and of the revolution of the cam, as indicated on the portion of the cam by the words, "pawl advances."

How the Cam Operates.—The cam is shown in its correct position at the downstroke of the press and with the die closed. It is observed that the contact between the cam and roller is such that the feeding direction of the cam lobes is always *down* in respect to the horizontal position of slide *G*. This is a desirable condition and one that is not often attained in feeding mechanisms of these types.

It is found that driving the pawl and dial by other methods, such as using an arm to the crankshaft, bell cranks, and various combinations of compound levers, will present several difficulties which are not encountered when employing such a driving cam as this, which makes one complete revolution while synchronized with the movement of the press crank.

Dials Use Simple Tools.—The dial stations are simply a circular row of equally spaced "nests" or dies, in which pieces of work are placed to be carried around under the punch for operations. The punch or punches are usually for perforating, spanking, riveting, or staking, and the latter operation predominates. The edges and indexing notches in the dial plates are hardened and ground to maintain accurate operations. Dials have been made to index within limits of plus or minus 0.002 in. The stop finger, driving mechanism, and retarding pawls are all hardened and ground to prevent excessive wear, so that all these working members will continue to perform accurate work indefinitely.


G
Pawl
E
D
H
G
Roller

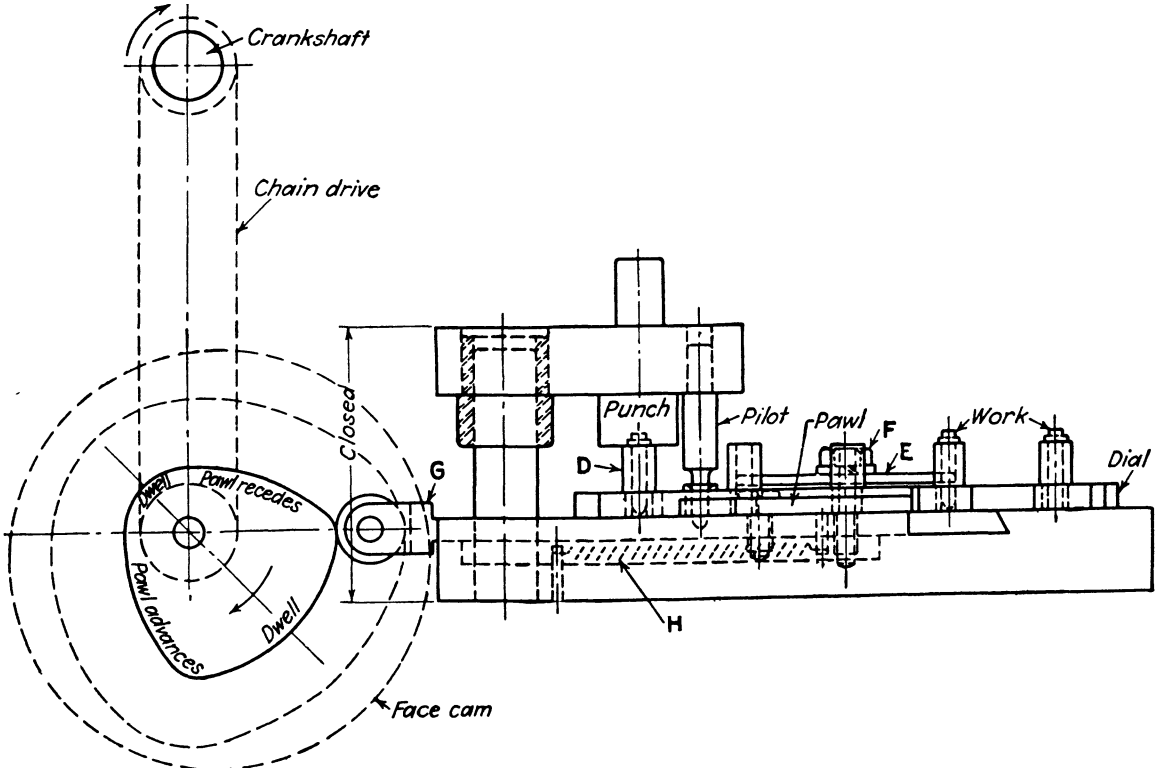


FIG. 123.—The design of a dial-feed press tool for swaging a copper band around the shell and delivering it automatically. A face cam, shown dotted and with a slot enclosing the roller, can be substituted for the edged cam. A slotted cam operates the pawl slide G both ways, making tension spring H unnecessary. This is an alternate design for the cam.

Safety Attachment Controls Press Clutch.—This device consists of an extra latch placed on the press clutch 90 to 100 deg. back of the regular latch. This attachment prevents tool accidents that occur if the dial is not properly indexed into perfect position while the punches descend. If the dial and its registering slot are incorrectly

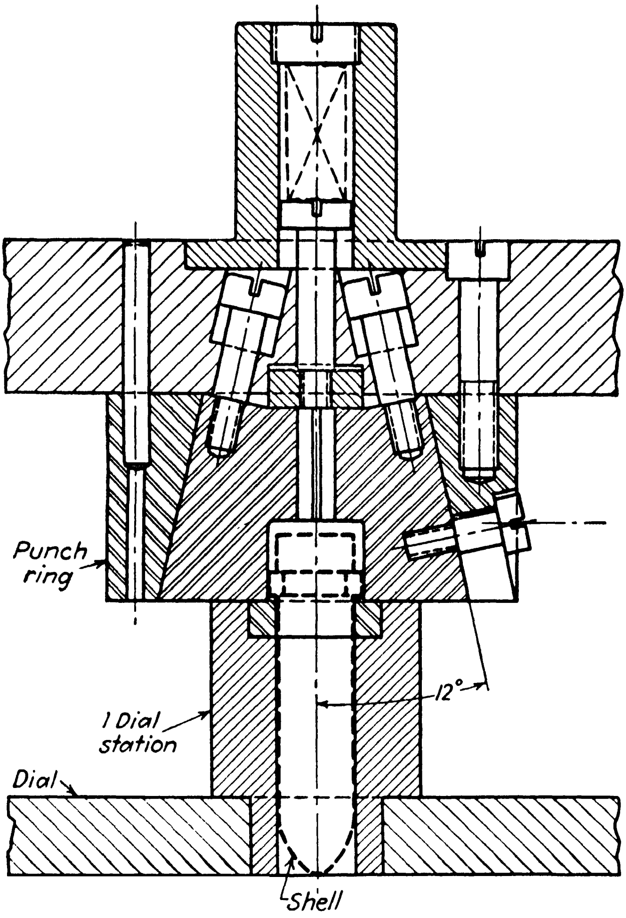


FIG. 124.—Cross-sectional view through a closed punch-and-die station used for swaging together a copper band and shell on a circular dial feed.

placed, the extra latch disengages the clutch when the slide has advanced halfway down, preventing the punches from wrecking the die, dial, and work. However, when this safety latch is attached on a large press, which has a heavy slide, it is best to counterbalance the slide to prevent its falling ahead. This difficulty occurs when heavy slides are released by the latch which disengages the clutch for preventing an accident to the tools.

Typical Punch-and-die Working Station.—Figure 126 illustrates the use of a circular dial plate carrier. The workpieces, a drawn cup, are simply dropped into "cupped" bushings around the dial and are carried to the die station where the punch pushes the pieces into the die and pierces a hole in the bottom of the cup. Workpieces may be pushed through the die, as in a redrawing operation, or pushed back into the bushing for ejection at a subsequent station.

Arrangement of Dial Feeds.—In Fig. 127 a hardened block is inserted in the dial bolster and under the working station. This is a case where the work is placed in the dies. The work is then carried around under the punch for staking, forming, or whatever is to be done. A die of this kind is shown in the cut. The operation is clinching together the parts of a caster wheel.

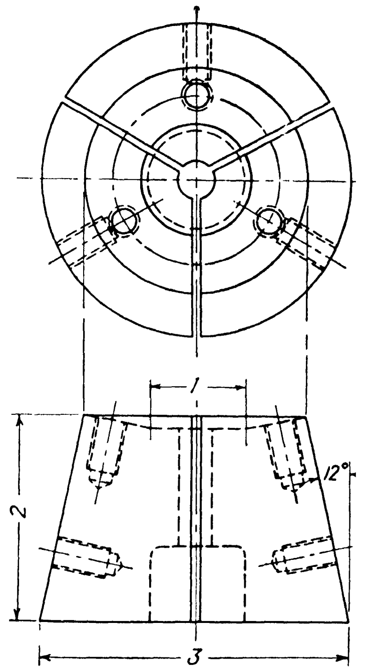


Fig. 125.—Details of the conical punch sectors that close and swage copper bands and shells and then open automatically to release them.

Assembling Roller-skate Wheels.—Figure 128 is a photograph of a dial feed mounted on a press and "tooled" for assembling roller-skate wheels or rollers. The roller is composed of an outside and inside shell, two ball races, and a double cone. The parts are fed by hand, but the balls are fed automatically. The ball hopper is seen at the front of the press. The feed is arranged so that a roller is completed at alternate strokes of the press, as the cone, one ball race, and a shell are assembled together. In the next stations, one ball race, the balls, and the other half of the outer shells are assembled. The final assembly is accomplished by placing the cone, ball race, and the outer shells in the stations. Then, as the dial is indexed, the punch descends and assembles these halves in the die. The parts are then carried under a staking punch and are securely staked in assembly. Two women operators are able to assemble from 20 to 25 completed wheels per minute.

Assembling Nuts in Jackets.—Another type of dial is shown in Fig. 129. This 12-station dial feed is used in connection with a hopper

feed at the left, for handling square nuts, and a chute with a slider feed at the right, for handling steel jackets in which the nuts are

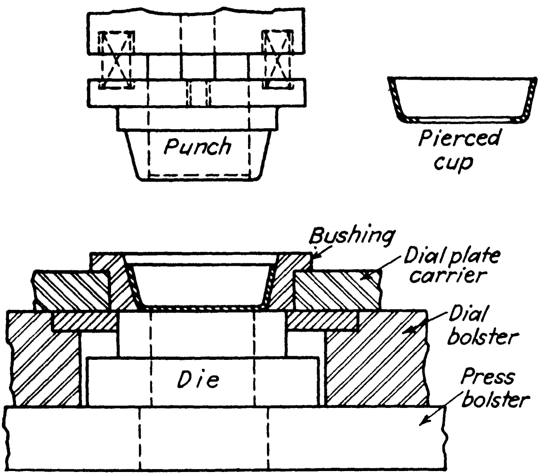


FIG. 126.—A typical punch and die, to which each of 12 equally spaced bushing stations are carried by consecutive movements of the dial. The work carried in the bushing is a drawn cup. A hole is pierced in the bottom of the cup at the punch-and-die station shown above. (*Courtesy of F. J. Littell Machine Co.*)

enclosed. The jackets that envelop the nuts are designed like a square eyelet and have prongs that can be clinched into holes in automobile

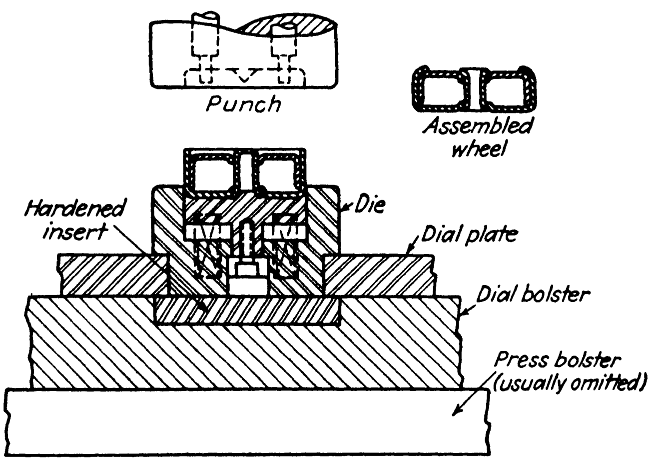


FIG. 127.—Dies can be located on a circle, one at each of 12 or more equally spaced stations, and then carried around on a dial under the punch at the working station of the press. This die assembles an ordinary caster wheel. (*Courtesy of F. J. Littell Machine Co.*)

bodies, or wherever nuts are required to hold certain parts with screws. Two women operators assemble 120 nuts and jackets per minute.

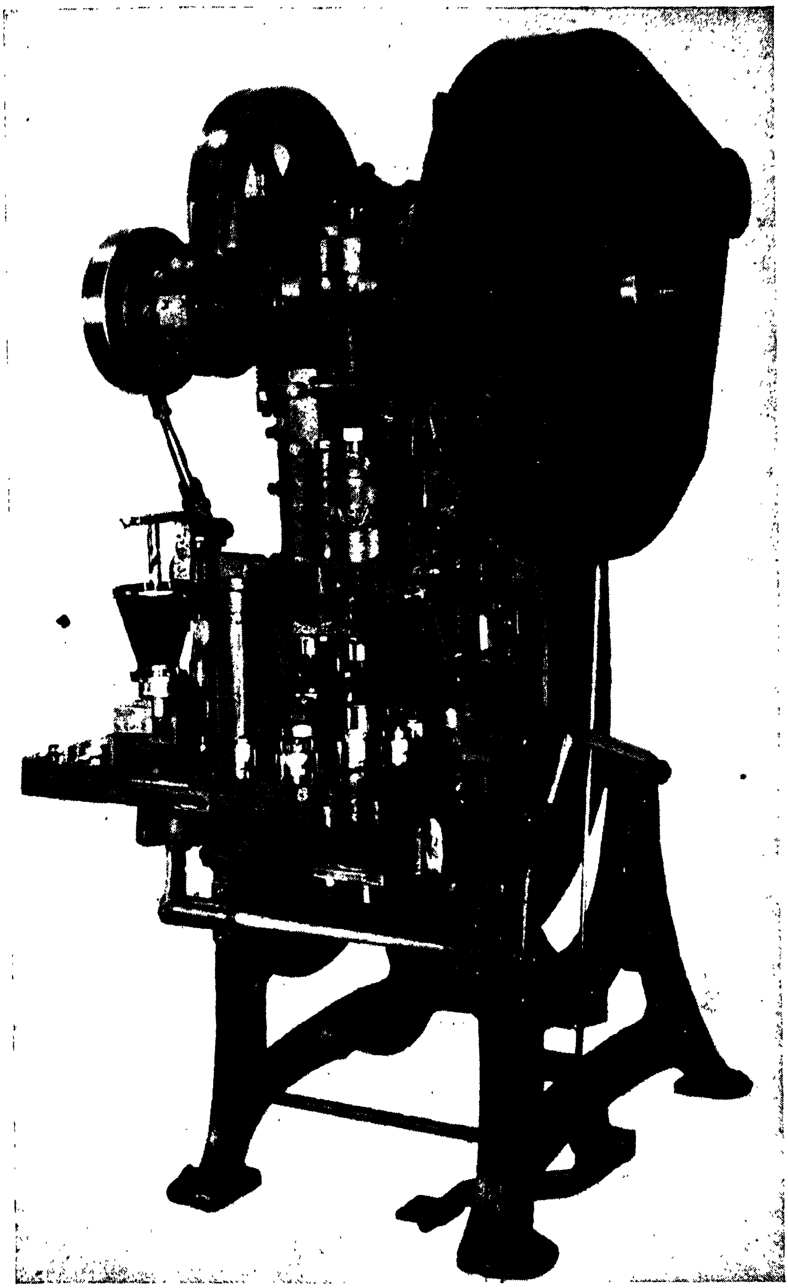


Fig. 128.—An interesting setup of a dial-feed punch and die for completing more than 1,200 assemblies of ball-bearing roller-skate wheels per hour. (*Courtesy of F. J. Littell Machine Co.*)

Assembling Wiper Contacts for Telephones.—Figure 130 illustrates a dial feed mounted on a special pedestal together with the press itself. In this case, the dial plate is operated by a separate motor and can be indexed 1 to 40 times per minute. The revolutions of the crankshaft

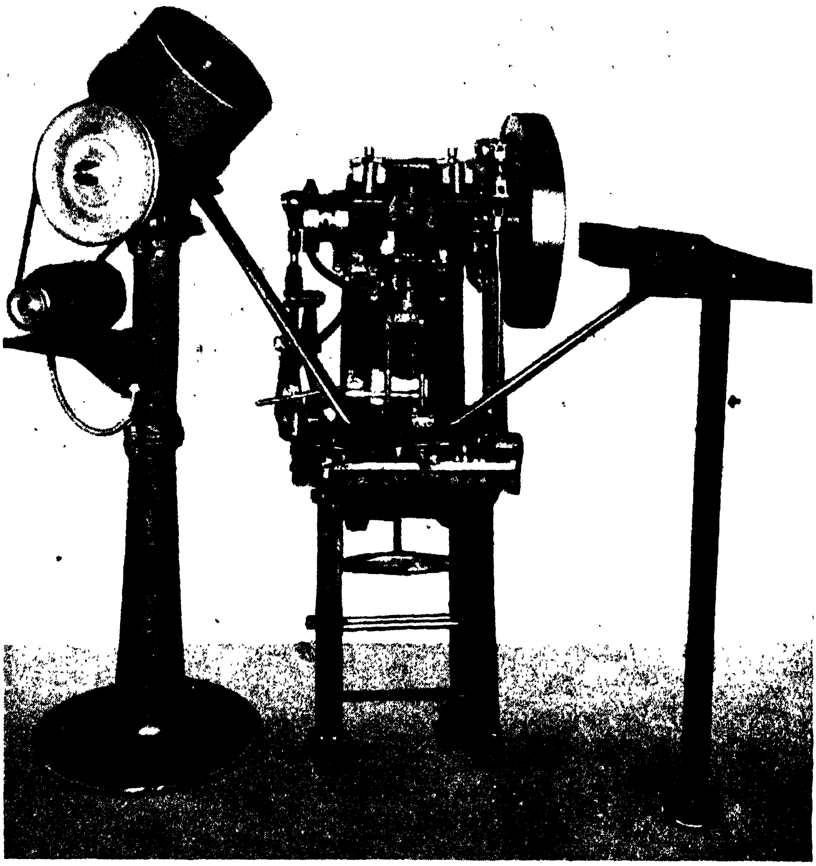


FIG. 129.—A dial-feed setup with auxiliary hopper and slide feeds in which over 7,000 square nuts with steel jackets are assembled hourly. (*Courtesy of F. J. Littell Machine Co.*)

are 100 per minute. The dial is arranged to "trip" the press only when the work is perfectly positioned. If, for any reason, the dial pawls fail to fall into their proper places, it is impossible to operate the press. This dial and its tools are used for assembling and staking wiper contacts in automatic telephone equipment. There are 10

parts in the assembly. The finished units are ejected by compressed air. Five or six operators are placed around the dial for feeding in the parts.

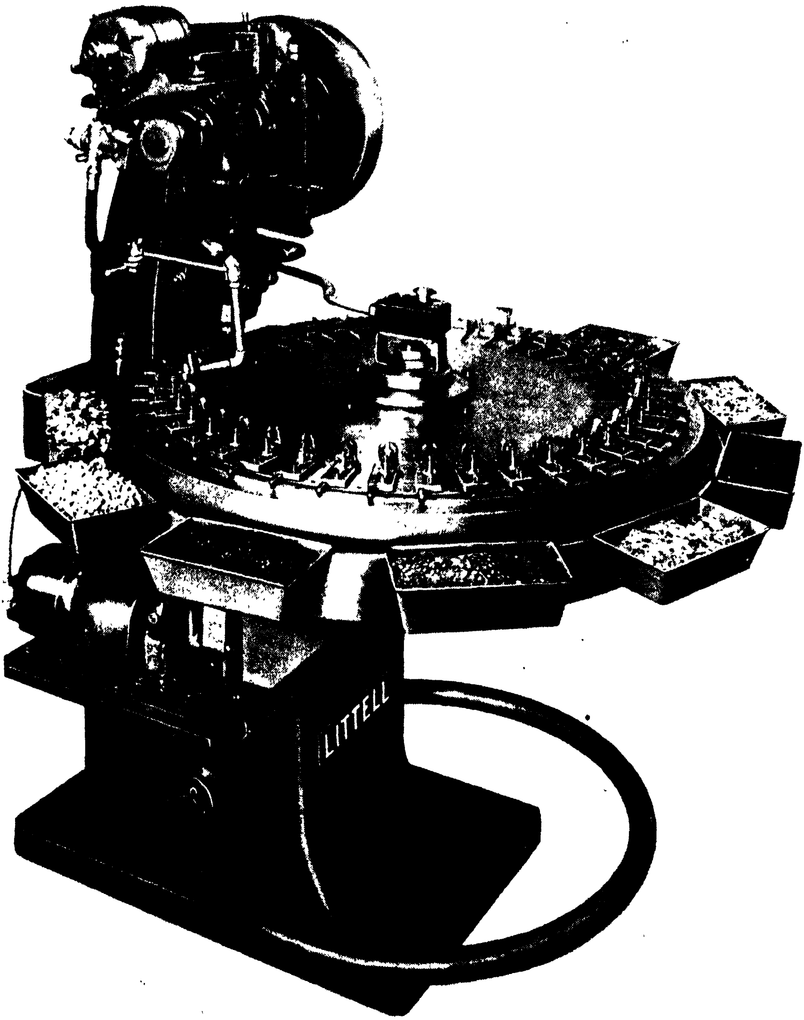


FIG. 130.—This dial has 40 stations; the working dial is 36 in. in diameter and 3/8 in. thick; the press crank makes 100 r.p.m.; the motor requires 1/4 hp. for 1,725 r.p.m.; the height of the dial plate from the floor is 36 1/2 in.; the over-all floor space, right to left is 44 in., front to back, 50 in. Notice the adjustable pipe for compressed air and the attached nozzle for blowing off finished pieces of work.

Press Speeds for Operating Dials.—To get the most efficient results from dial feeds, the press should not be run faster than the operator

can feed the parts into the dial and load every station. When the parts must be carefully located in the dial, or where two or three parts are fed into the dies, the speed of the press must be reduced accordingly. However, with a variable-speed transmission, the operator can easily control the press speed as desired.

Size or Tonnage of Press.—The tonnage rating of presses, as given by the press builders, is based upon the flywheel running a given number of revolutions per minute. Any variation from these speeds affects the foot-pounds of energy as the square of the speed. For example, if a press rated at 30 tons capacity at 120 strokes per minute is reduced to 40 strokes per minute, the foot-pounds of energy are then reduced as the square of 120 is to the square of 40, or to one-ninth of the original energy, which is only $3\frac{1}{3}$ tons. For slow speed, or heavy work, geared presses are employed.

Stroke of Press.—Dies should be carefully checked to determine the required stroke of press. One hundred and eighty degrees, or one-half of the press cycle, should be allowed for indexing the dial. This means that the punches must clear the work or dial and dies, leaving the dial free to turn during one-half of the press stroke, or 180 deg. These features also provide time for operating a safety latch on the press, and they apply when the dial is being indexed during the upstroke of the press ram.

Safety Stops.—When presses operate with pin clutches it is necessary to provide a special "throw-out latch" located about 90 to 100 deg. back of the regular latch. This latch is operated by a cam on the clutch collar, together with a pilot that enters a notch in the edge of the dial. If the pilot fails to enter a notch in the dial, the latch stays locked, but if the press is driven by an electrically operated pneumatic clutch and brake, the stopping must be accomplished by using microswitches, operated by the stop and retard pawls on the dial feed. Another switch is placed on the dial drive connecting rod at shear pin *A*, as shown in Fig. 131. These switches are marked *B*, *C*, and *D*. *B* is at the stop pawl, *C* the retard pawl, and *D* the drive pawl. All switches are normally open when the dial is properly indexed.

Size of Dials.—The number of stations in the dial depends upon the speed of the press. It is obvious that the faster the press operates, the more stations the dial requires. Standard dials are built with from 6 to 24 stations. Diameters range from 10 to 36 in. However, some special dials are made larger. Most dial-fed ratchet disks are provided with square notches. When fully indexed, the dial is firmly locked in place between two pawls, as shown in Fig. 131. Dial feeds

like this one can be made to operate very accurately. It is possible to grind edges and notches after hardening, so that the dial can be indexed within limits of plus or minus 0.002 in., or better.

Dial Feeds Are of Two Classes.—The first class is where the dial is mounted on a special bolster, which is used in place of the regular press

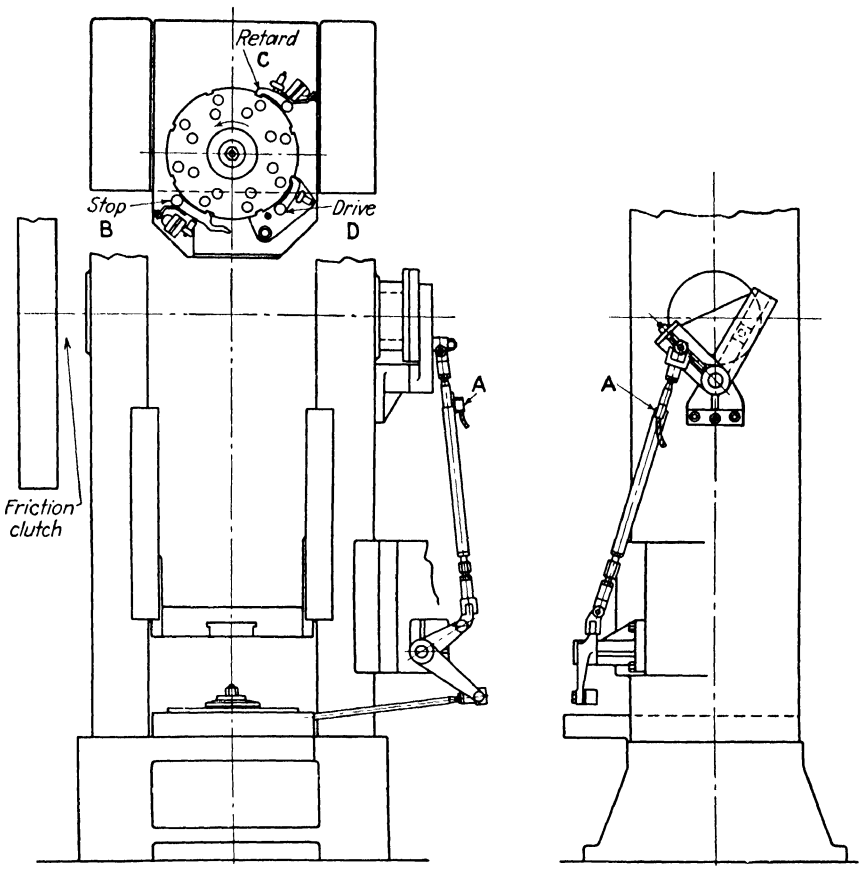


FIG. 131.—A typical dial-feeding mechanism showing the stop with retarding and driving pawls in place. The driving-crank disk, the bell crank, the operating arms, and the adjustable thrust rods are also shown. (*Courtesy of F. J. Littell Machine Co.*)

bolster; there is a die or fixture at every station in the dial. The bolster is provided with a hardened anvil under the working stations of the dial, and parts are fed into the dies or fixtures and are then indexed around under the punches. One advantage of using dial feeds is that more than one operation can sometimes be performed on the same piece while it is being indexed under different punches.

Ejecting the finished parts is accomplished in several ways. (1) Punches can be made to "pick up" the pieces and eject them at the top of the stroke. (2) An air blast can be used to blow them clear of the dial. (3) A special "pick off" can be arranged to pick the pieces out of the dies and eject them over the dial. Two of the meth-

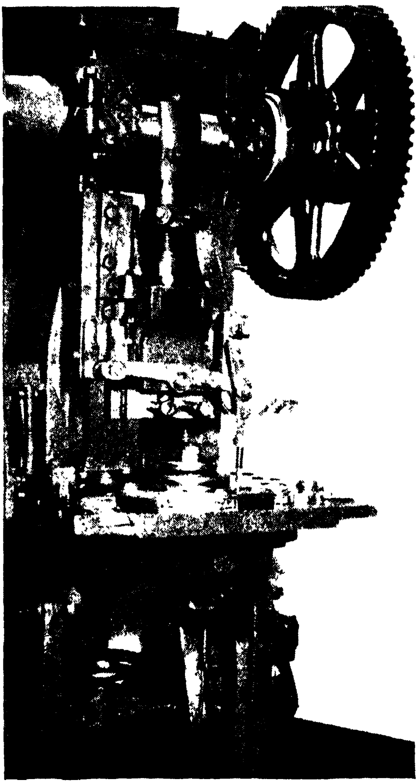


FIG. 132.—Position of special pick-off arm just before the press slide releases it to eject finished work from the dial.

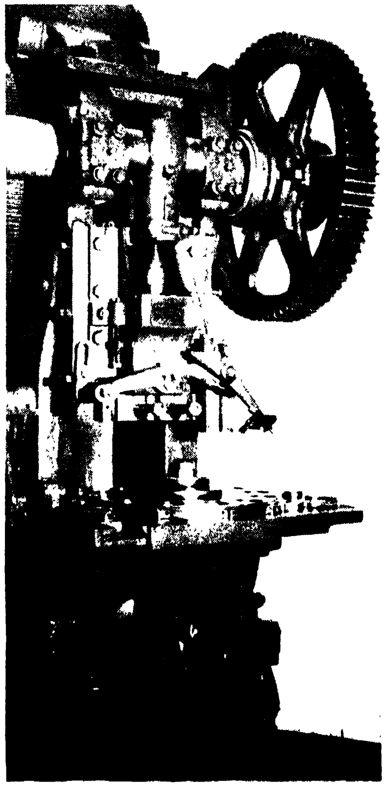


FIG. 133. Ejecting position of pick-off arm after it has been released.

(*Courtesy of F. J. Littell Machine Co.*)

ods are shown in Figs. 130, 132, and 133. The setup shown in Figs. 132 and 133 is adaptable for assembling such work as skate rollers, casters, wheels, doorknobs, lock parts, staking operations, detonators, fuse parts, and for broaching socket wrenches.

The second class is where the dial is mounted on a special bolster plate that rests on the regular bolster of the press. It has an opening under the working stations for inserting dies under the dial. The parts are fed into openings in the dial, and the dies must be carefully fitted

in the dial bolster so that there will be no obstruction to prevent the parts from being moved freely over the dies. Sometimes it is necessary to fit a plate between the die and bolster to obtain free movement of work. This type of feed is adaptable for drawing cartridge cases, broaching work, piercing, and trimming. In this type the finished parts are usually pushed through the dies, though in some cases they are carried to a subsequent station, where they are dropped through a hole in the bolster.

Under-drive Dial Feeds.—This style differs in construction from the regular dial feed inasmuch as the dial that carries the dies and work is a plain disk, as shown in Figs. 134*A* and 135. The disk can be made from any hard material of the required thickness and diameter. As the name implies, the work dial is indexed by a separately notched dial mounted underneath the work dial to which it is attached with screws and dowel pins. Since the work dials are comparatively inexpensive, a separate dial can be provided for each job, and interchanging dials on the machine is quickly done.

The indexing dial must be made accurately. It should have hardened and ground edges and notches so it can be indexed within limits of plus or minus 0.002 in. The indexing dial is usually about one-half to two-thirds the diameter of the work dial, as indicated in the drawing, Fig. 134*A*.

A supporting ring is placed under the work dial, and it should extend sufficiently far under to support the parts being fed into the dial, as shown in the drawing. The supporting ring can be cut away in the back to expose the dies placed under the dial. The dial is indexed by an adjustable eccentric on the crankshaft of the press and is driven through a bell crank to the sector arm on which the drive pawl is mounted. This style of work dial can be adapted to performing many different varieties of dial presswork.

Motor-driven Dial Feeds.—(Patents applied for.) The motor-driven dial feeds are constructed practically the same as the under-drive feed with the exception of the drive itself. The arm that carries the driving pawl, Fig. 134, can be activated by either a cam or a "shaper movement." Either of these drives can be made to index the dial in 120 deg. of press-crank movement, or less. The shaper-movement drive or cam is motor driven through a 3 to 1, or 6 to 1, variable-speed transmission. Obviously, this arrangement gives a wide range of speeds. Its advantage is that the press can be operated at its normal speed because the dial and its feed are not synchronized with the press. The press should be equipped with a nonrepeat clutch and a solenoid trip. The switches that operate the

press trip are actuated by two of the pawls on the dial feed, as seen in Fig. 131, at *B*, *C*, and *D*. The third is actuated by a cam on the shaper-movement eccentric disk or drive cam. In this arrangement, when the dial is properly indexed, the stop and retard pawls are seated, and the switches operated by them are closed, after which the switch on the cam or shaper eccentric closes, and the press is then "tripped." This style is ideal for assembly operations because the speed of the dial can be easily controlled.

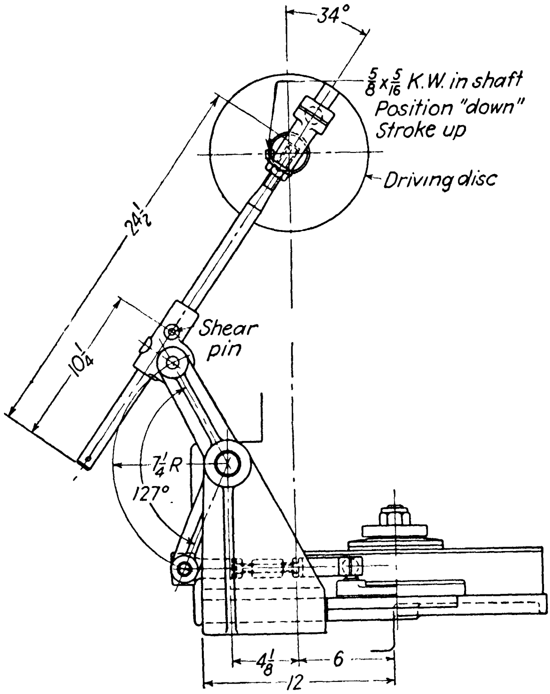


FIG. 134.—Left-hand projection of the lower view shown in Fig. 134*A*.

Practical Setup of Underfed Dial.—Figure 136*A* shows a typical setup for an underfed dial in which an electrical terminal is fabricated. This drawing, lent by F. J. Litttell Machine Co., shows the necessary dimensions for arranging an underfed dial on a No. A-3½ Niagara Press. There are four die operations: flattening, piercing one hole, trimming flash, and stamping letters. The pick-off mechanism is not shown but is similar in principle to the one shown in Figs. 132 and 133. There are 24 equally spaced work stations around the dial, at each one of which pins are located for positioning the parts.

Cartridge-case Dial Feeds.—Figure 137 is an interesting setup of five straight-side presses (some with dials), for producing 20 mm.

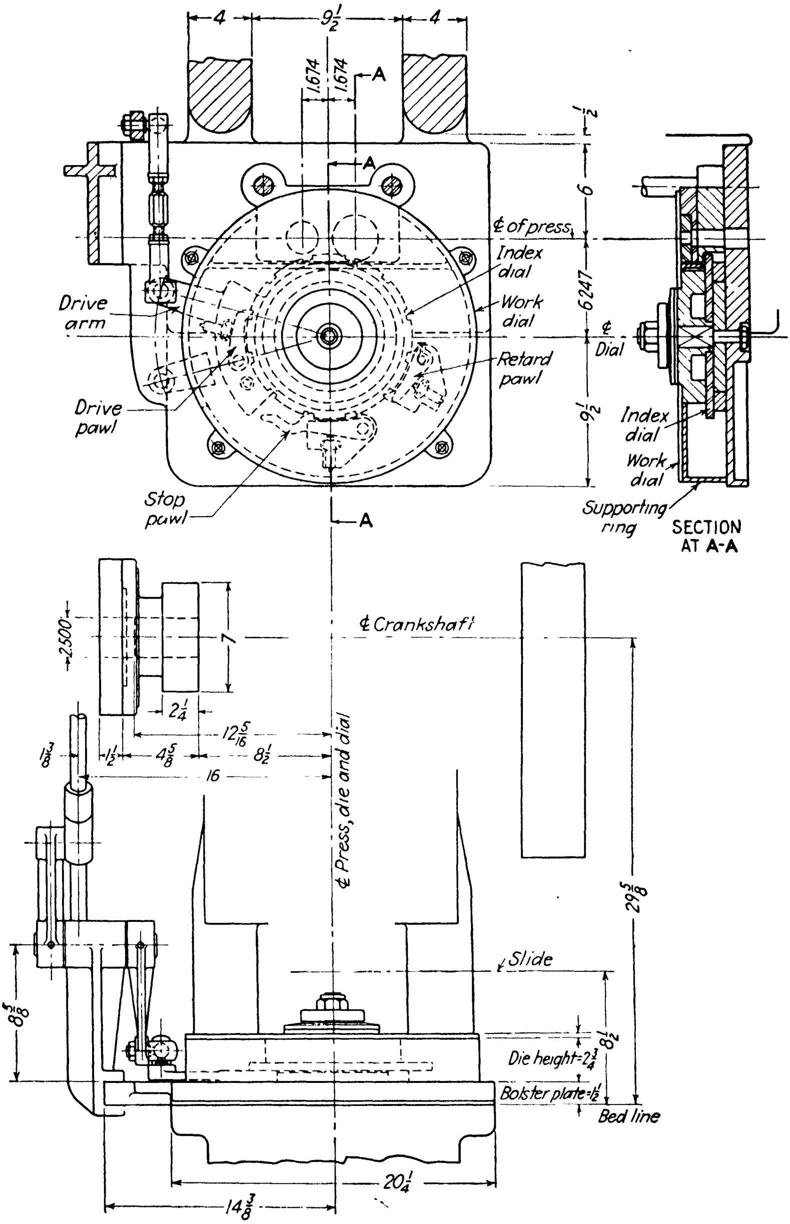


FIG. 134A.—Details of an under-drive dial feed mounted on a No. 4½ Niagara Press. (*Courtesy of F. J. Littell Machine Co.*)

cartridge shells. At the lower left is seen the blank, first draw, and three redraws of the shells.

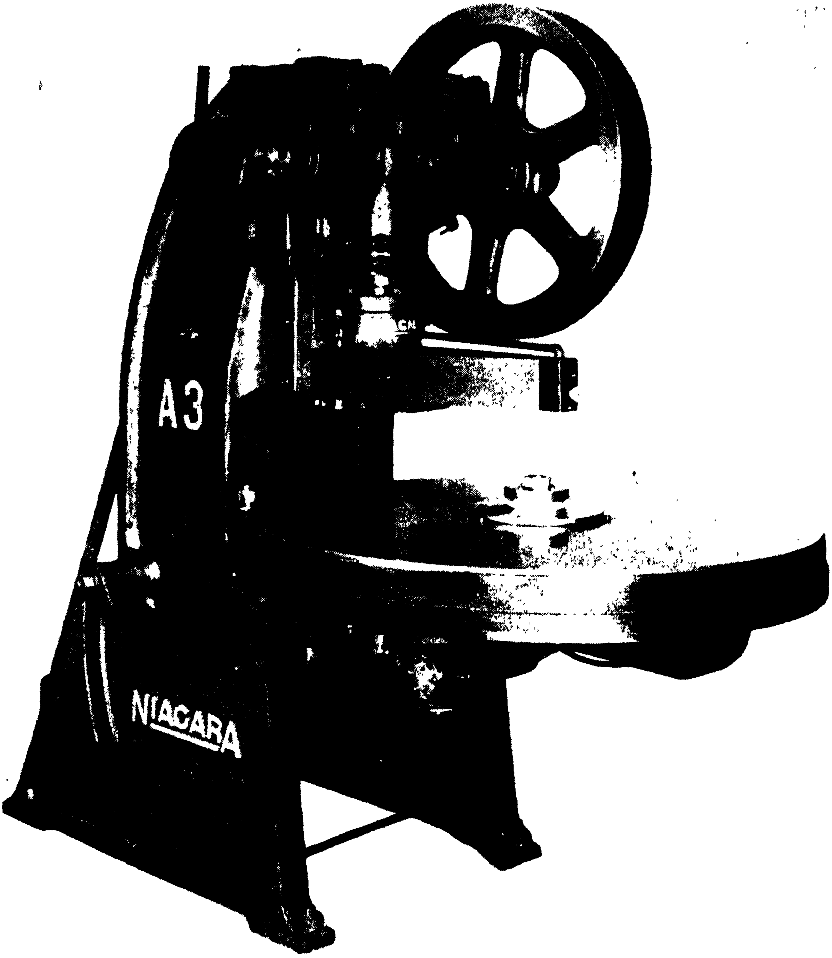


FIG. 135.—This work dial is 48 in. in diameter and is used for assembling the sections of toy train tracks. It has the under-dial type of feed attached underneath the work dial. The under dial is driven by a $\frac{1}{2}$-hp. electric motor. This type of press is particularly well suited to handling large and medium sizes of various assembling operations. The machine has a safety attachment that prevents press operations if the dial is improperly positioned. (*Courtesy of F. J. Littell Machine Co.*)

The lower right-hand view shows a close-up for one of the dial feeding units. This dial feed is used for "cupping" operations, such as the first and second draws. Dial-feeding units such as these are used in the production of cartridge cases up to 105 mm. diameter.

The dial is bored at eight equally spaced positions to receive suitable adapters for carrying the work intermittently under the center of the press, ram where it is permitted to drop into the die, one piece at a time. Indexing the dial is effected through a shaper-motion arm at 120 deg. revolution of the press crankshaft.

In operation, the press operator drops work into the adapter, one of which is located in each bore of the dial, whence it is carried halfway around over the die and directly under the punch. At this point the dial is electrically inspected automatically. This inspection determines whether or not the shell is properly registered under the punch. If the registery is correct, the ram is permitted to descend and the punch draws the shell down into the die. When the punch ascends, the work is stripped off underneath the die and then falls out below.

Feeding and Transferring Shells.—The following system is used in transferring shells from station to station for redrawing them. It is the horizontal progressive blade feed used on multiple drawing presses. These presses may have several vertical drawing stations in line, five being the usual limit. Drawn cups are fed to a continuously revolving friction dial, from which a finger controls the entrance of each shell to the first die.

Astride the full length of the dies are two parallel horizontal bars having V-shaped notches on their inner edges at each side of the die stations. When the ram descends, these bars are separated by entrance of the punches. Tension springs return the bars together into normal position after the punches ascend. When the punches rise, the knockouts under the dies bring the bottoms of the cups up flush with the top of the dies. The two bars then close together and hold the shells in the V-notches at each station, and next they move forward one station. This cycle is repeated at each press stroke, with one shell feeding in at one end and another leaving the press finished at the other end, while shells in between are being redrawn at each station. The carrier bars slide back to their normal position while the punches descend. The V-notches, of course, must fit the outside drawn diameter of the cups at each of the stations.

Automatic Hook Feeds.—In blanking dies, where a scrap frame passes out an efficient hook feed can be designed and built into the die. It thus becomes a functional part of the tool, and automatic stops are unnecessary. The idea is presented in Fig. 138, and the operation is shown at the bottom of the press stroke. The simple operating mechanism consists of a horizontal cam slide fitted between two guides. This cam slide is positioned parallel with the work strip at the left of the die and beside the upper edge of the strip.

A "hook feed" is attached by a fulcrum screw to a block secured at right angles across the horizontal cam. A flat spring forces down the tooth on the hook so that it slides on a plane coincident with the die-block surface. The hooked tooth engages over the "bridge" in one of the blanked holes of the scrap. When the ram descends, the vertical

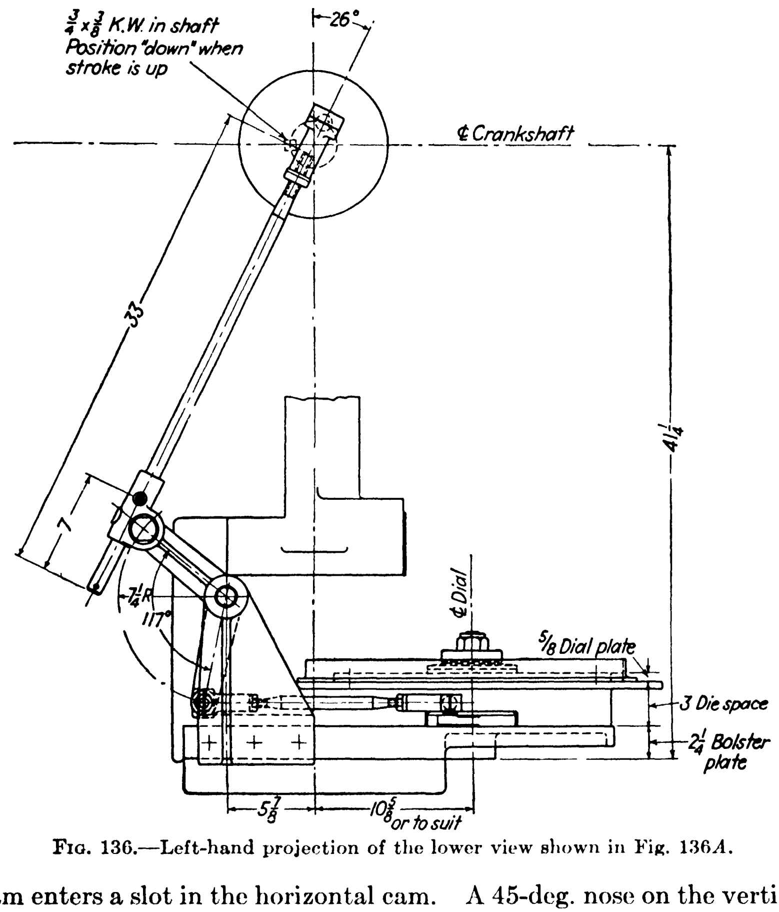


FIG. 136.—Left-hand projection of the lower view shown in Fig. 136A.

cam enters a slot in the horizontal cam. A 45-deg. nose on the vertical cam pulls the hook and strip toward the left equal to a distance of one blanking center, or C. This movement exposes an uncut portion of the work strip to be pierced and blanked. Meanwhile, the vertical cam locks the hook in place, by entering a dwell space A, which occurs just before blanking.

When the vertical cam ascends and the work material is stripped, a compression spring causes the horizontal cam to advance toward the right until the tooth engages over the next scrap bridge. This occurs

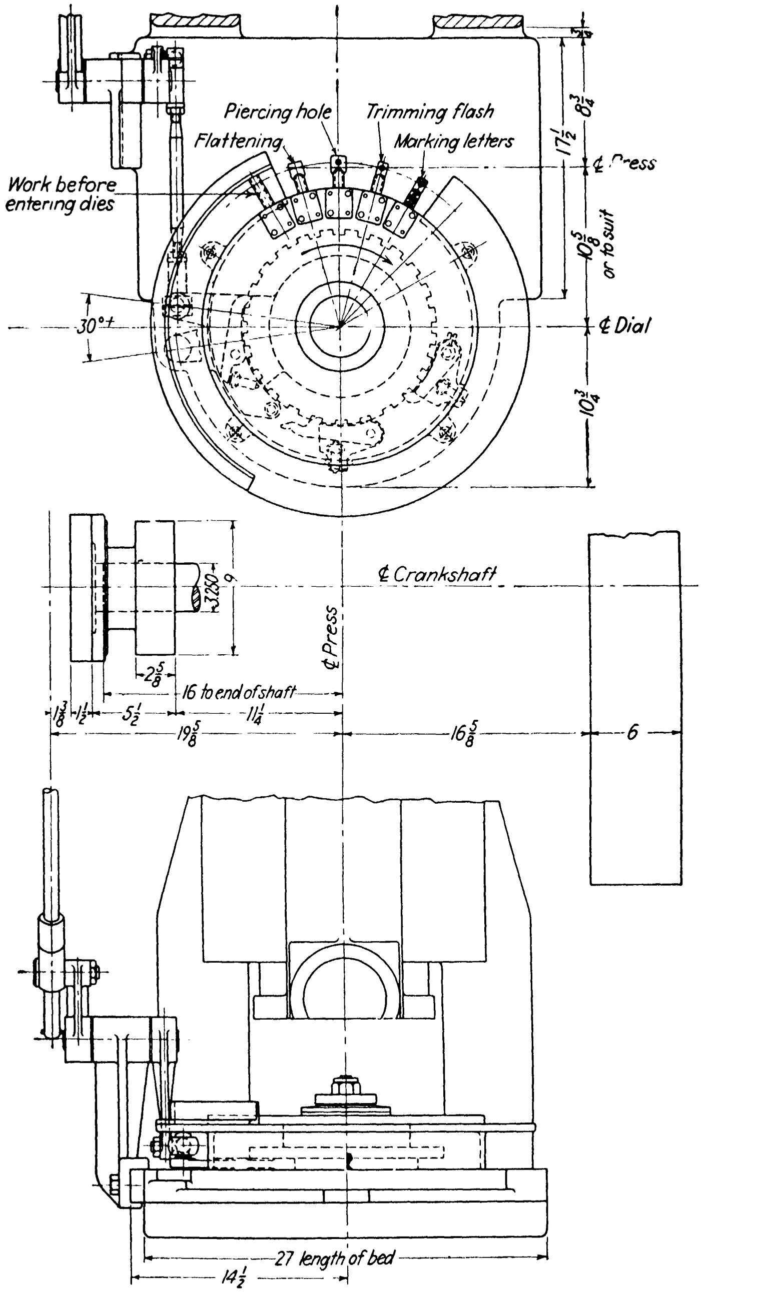


Fig. 136A.—A 24-station underfeed dial designed for flattening, piercing, trimming, and stamping characters on electrical terminals.

when the left edge of the slot in the horizontal cam begins to ride on the dwell space *B* of the vertical cam. Although the *rise* on the vertical cam nose is 45 deg., in this case it is obvious that its *run* is also equal to blanking center distance *C*.

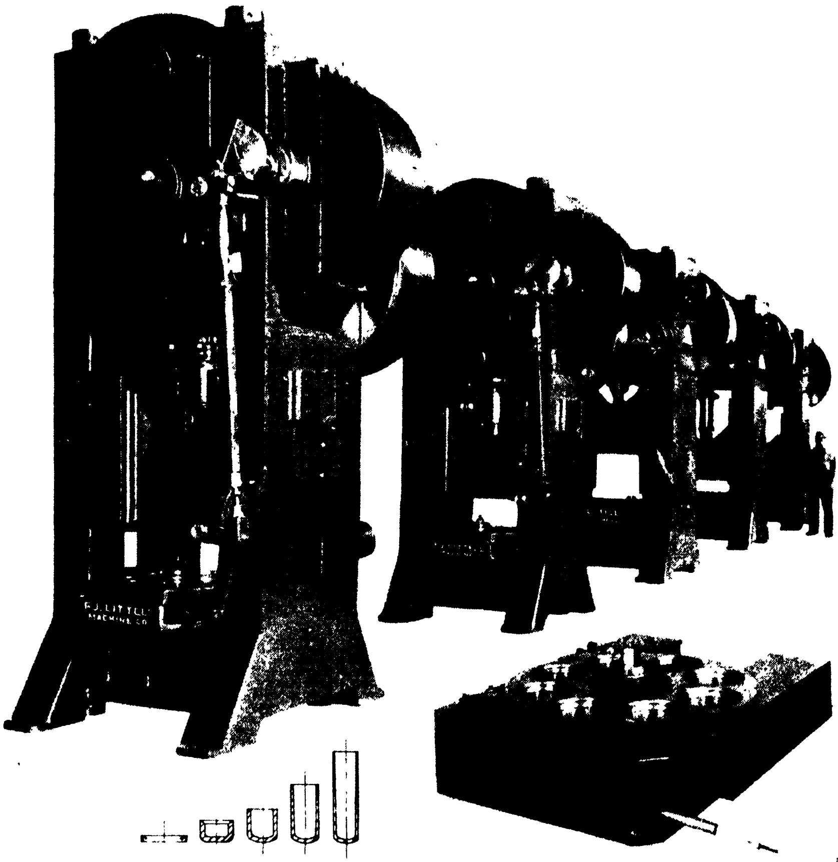


FIG. 137.—This battery of five large straight-sided presses, with the dials shown on them, is used for blanking, drawing, redrawing, and marking 20-mm. cartridge shells.

A brake to prevent overfeeding consists of two spring rollers. These ride against the front edge of the work strip, as shown.

Hitch Feeds.—Another feeder is called a "hitch feed." It is designed for handling light-gage strips up to about 8 in. wide. The body of this feed is attached on the right end of the die shoe, for right to left feeding, and $1\frac{1}{2}$ in. is left open on the surface of the die shoe for attaching. However, this feed has also been successfully used when attached on a block over the die shoe flange. The feed is operated by

an angular lug secured on the punch holder. When the ram descends, the angle on the lug contacts a roller on the feeding slide, causing it to recede for the next "throw." A "pinch check" against the surface of the strip holds it from slipping back while the jackknife grip in front of the check takes hold. When the ram ascends, a tension spring attached on the feeding slide pulls the slide and strip forward a distance equal to the blanking centers of the die. The angle and width of the

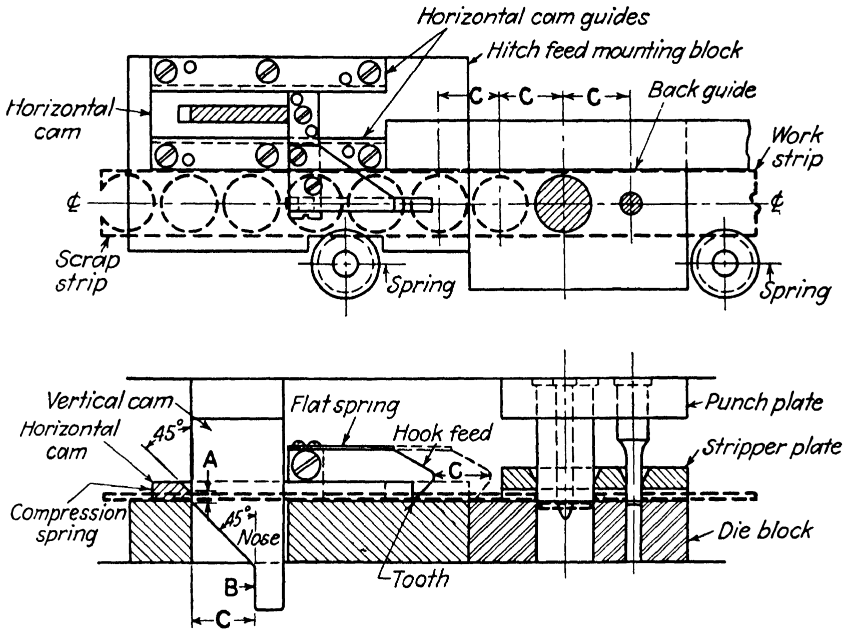


FIG. 138.—In this automatic hook-feed, a horizontal latch hook is positioned over the scrap strip at the left end of the die. The hook engages in the blanked openings and pulls the strip forward one station when the ram descends. This blanking die does not require an automatic stop.

operating lug must be designed to suit each job, but this is a very simple layout, which can be done in a few minutes (see Plate XVIII, page 425).

Roll Feeds.—These feeds are made in two styles, single and double sets. The single set, Fig. 139,* is used when the material strip is heavy enough or stiff enough to be positively pushed across the dies without buckling, or when no scrap strip is left after blanking for an opposite set of rolls to grip. If a single set of rolls is used on the left side of the press, as shown in the figure, they can pull the strip across the die, if the scrap frame that remains after blanking is strong enough to prevent its breaking.

* For the double set, see Fig. 146.

Driving the rolls is done either by a toothed rack meshed with a pinion "keyed" on the lower roll or by a pawl and ratchet movement. The operating arm is connected to a crank disk keyed on the crankshaft, or to a slide in a slotted crank block, as shown in the figure. In either case, changing the crank "throw," by adjusting the position of

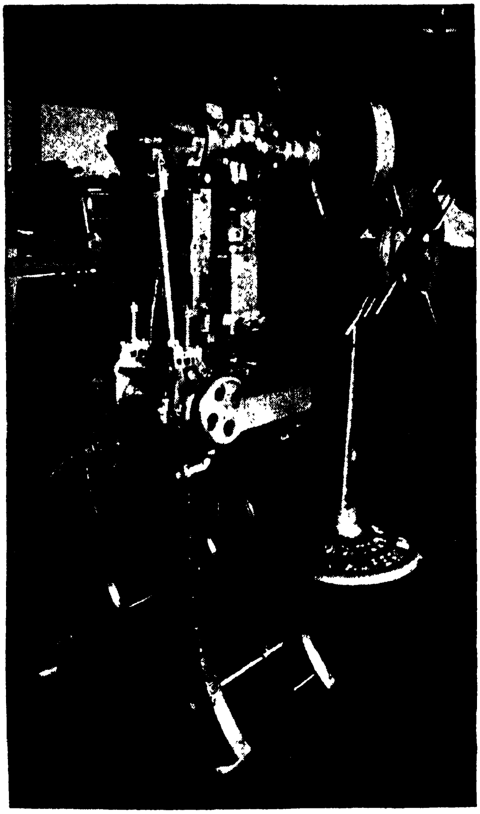


FIG. 139.—This pair of feeding rolls is attached on the left end of the press bolster plate. The rolls pull the strip across the dies from a reel at the right side of the press if the scrap frame is strong enough to resist breaking. Rolls of this type are also used for feeding the strip from left to right. (*Courtesy of U. S. Tool Company.*)

the block in the slot, will vary the feeding length. Usually there is some kind of release provided to raise the upper roll. This feature permits the pilot pins in the press tool to register in the strip just before blanking occurs. The ram, in descending, trips a lever that separates the rolls. The relief lever is also used to separate the rolls when inserting the end of a new strip. Using this relief in all types of roll feeds is advocated in cases where pilot pins must positively register in the strip, from previously pierced holes, before blanking begins.

Since roll-feeding mechanisms are comparatively simple and of rugged construction they are adaptable for handling a very wide range of thicknesses and widths of sheet materials. It is principally for this reason that roll feeds have been generally adapted in pressrooms for advancing sheet and strip stock into presses for die operations.

To get the best results when equipping presses with roll feeds, not only the press, but also the press tools and the kind of material to be handled must be taken into consideration. The press to be equipped must have sufficient capacity in both tonnage and foot-pounds of energy to carry the entire load when operated at normal speed. The best results can be attained only when the press is operated continuously, since feeding is done partly on the upstroke and partly on the downstroke of the press.

Of course, stopping of the press occurs at the top of the stroke and at a moment when the feeding rolls are traveling at their highest speed. The rolls thus have a tendency to "coast"; they will not stop so quickly as the press, and coasting has been found hard to control. This difficulty is especially likely to occur in high-speed presses operated by pin clutches. In slow-speed presses having block clutches, or presses operated with a friction or pneumatic clutch and brake, the coastings are not so noticeable.

The press stroke required for the successful operation of feeding rolls is largely governed by the styles of dies used. For plain blanking dies, or progressive dies, in which the finished parts are discharged through the bed of the press, the press stroke should be long enough to allow at least a 180-deg. arc for the stock to be fed ahead after the punches and pilots clear the dies and work material.

Where compound dies are used for deep forming or shell drawing, the press stroke must be at least three or four times the length of the deepest draw or length of shell. This allows time and space for ejecting the parts from the dies. Air blasts are used in clearing pieces and parts from press tools.

The guides on dies should be designed to confine the work material on top and bottom as well as at the sides. The top confinement can, of course, have a small clearance space. The outer lengths of the guides should extend close up to the feeding rolls on the ingoing side. Especially should this feature be included in the case of using light sheet, say below 14 gage size. If these precautions in the guides are neglected, thin stock may "buckle" or bend and thus cause inaccurate feeding.

"Homemade" Feeding Rolls.—Several plants have recently introduced their own design of high-speed feeding rolls, as illustrated in

Fig. 140. The setup is a very simple and cheap one to make in any machine shop. The only material required is a pair of small spur gears between the roll centers (not shown), two steel rolls and bearing blocks, four sprocket wheels, a pair of small miter gears, and two lengths of sprocket chains. A base plate and a retaining frame for the rolls are also shown in the sketch. Most of the materials can be "picked up" around the shop. A "safety-first" cover is placed over the finished assembly.

Two compression springs mounted over the top bearings of the upper roll allow for feeding various gage thicknesses of strip between

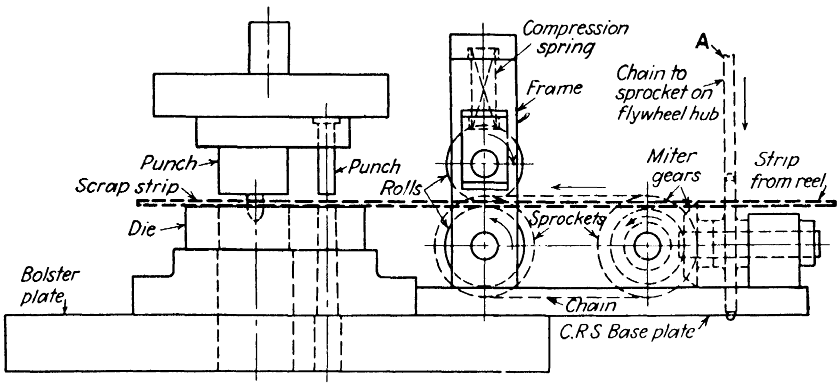


Fig. 140.—Pair of rolls for feeding strip over dies from right to left. This setup is for high-speed work. Rolls are driven by miter gears and sprocket chains located behind the strip. Driving chain A is driven from a sprocket wheel centered on the flywheel hub.

the rolls. This feed is an excellent design for feeding strip into high-speed dies which are set up in gap-frame presses. Sprocket chain A is the main drive, and it is meshed with a small sprocket wheel centered on the flywheel hub.

To suit different speeds of presses, and for the movement of the strip at various lengths of blanking centers, the speed of the feeding rolls can be varied by using a driving sprocket of suitable numbers of teeth. The rolls are intended to "slip" on the strip during the time of stopping and blanking, which is an instantaneous interval.

Automatic Stop for Continuous Feeding Rolls.—In Fig. 141, the principle is shown for using a straight-punch automatic stop, which enters the die ahead of the blanking punch. This type of stop can be used successfully where the strip is being continuously fed forward by rolls or by other means. It is used extensively in connection with high-speed blanking dies using the continuous feeding rolls just described.

As seen in the sketch, the stop is located two stations beyond the blanking die. In operation, if the length of the stop punch is too long, it will enter the die before the second "bridge" has been sufficiently advanced and then "jam." On the other hand, if its length is too short, it will fail to enter the die soon enough and would then jam the first bridge. However, if the length of the stop lies between these two extremes, it will enter the die at the right time and stop the strip correctly. Width B of the stop should never be greater than half the width of C, which is the blanked width of opening in the scrap frame.

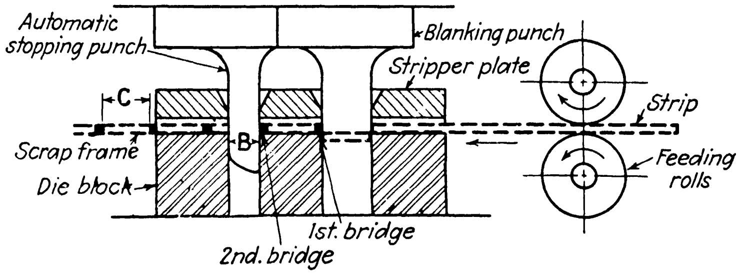


FIG. 141.—The vertical automatic stopping punch B enters the blanked opening in the scrap and registers the strip for cutting the next blank. This type of stop is intended for use where the strip is being steadily advanced over the dies by a pair of feeding rolls similar to those shown in the preceding sketch.

Difficulties in High-speed Feeds.—Quantity production for piercing and blanking of sheet metal parts has increased so enormously in recent times that much new development work was found necessary. This was especially true in cases where mechanical feeds were employed. These feeding devices are employed in both gap-frame and straight-side presses. But gap-frame presses are usually operated at more reasonable speeds than straight-side presses, the latter being run so fast, sometimes, that the feed actually becomes the limiting factor.

When the strip is started from rest, fed a considerable distance, and then suddenly brought to rest for blanking, in extreme cases the sudden jolt tends to pound the feed to pieces, or to cause inaccuracies and overriding, which cannot always be overcome by entering pilots or making allowances in the dies.

Press builders and manufacturers of automatic feeds endeavor to overcome these difficulties by incorporating heavier working parts and hardened and ground alloy steels of high wearing qualities. To take care of overriding, a friction thrust of one or more sheave wheels bear against the edge of the sheet or strip. A variable stop is used which pushes back the strip so that pilots are permitted to enter their locating holes and thus register the strip for correct blanking.

Roll Lifters.—Figure 142 shows a single pair of feeding rolls mounted on its own bolster plate. This set of rolls is equipped with an automatic roll release. This relief lifts the upper roll at each downstroke of the press slide to allow the pilots in punches to do the final

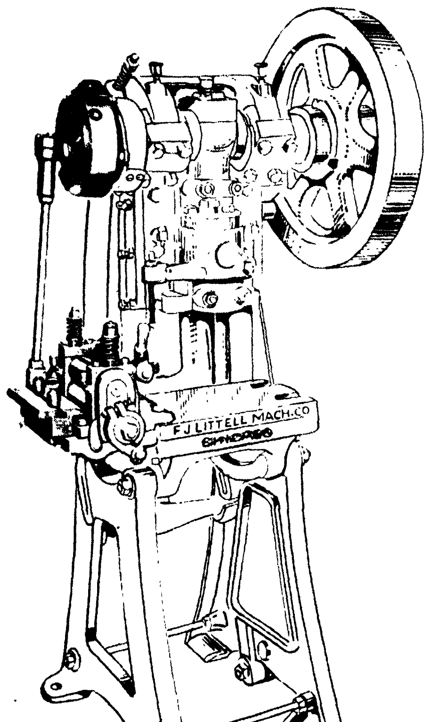


FIG. 142.—A single pair of automatic feeding rolls showing the roll-release lever attached across the front of the ram. An adjustable finger, in descent, releases the upper roll on the strip so that the punch pilots may enter the previously punched holes and thus register the strip before blanking. A similar release is also used when a new strip is entered.

locating of the stock strip in the dies. It registers the strip just before blanking begins. However, different styles of dies necessarily require different types of roll lifters, as follows.

Standard Automatic Roll Lifters: These lifters are used with plain blanking and progressive dies. As illustrated in Fig. 142, they are actuated from a bracket attached across the slide, and the timing of

the lifts is regulated by setscrews. On this style the amount of lift is limited.

By-pass Automatic Roll Lifters: These lifters are used where long pilots, deep forming, or drawing is done in progressive dies. On this

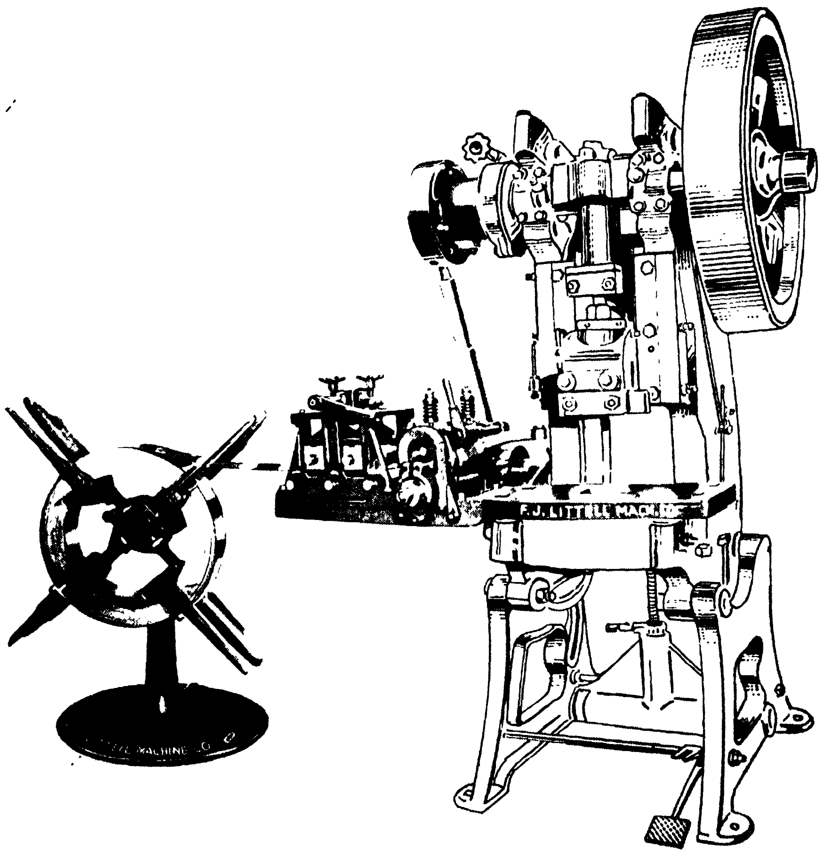


FIG. 143.—A ball-bearing reel with coil from which strip is pulled through a roll straightener by a pair of feeding rolls. The rolls and straightener are mounted together on one base plate.

style of lifters the amount of lift and the timing of the lift can both be regulated.

Cam or Eccentric Roll Lifters: This lifter is used on very large straight-side presses. This style is necessary where upper feed rolls have to be lifted for piloting and then grip the stock again before the pilots leave the surface of the stock.

Hand Roll Lifters: Hand roll lifters are provided so that one or both upper rolls can be lifted and left open when desired.

Automatic Roll Release: This is a "gag" arrangement attached to the ingoing feed. It permits the operator to place stock in the die so that he can start in the end of each strip or coil with a full blank.

Roll Feeds and "Safety First."—Presses equipped with automatic roll feeds carry the lowest accident insurance rates, as they eliminate the necessity of the operator's ever placing his hands between the

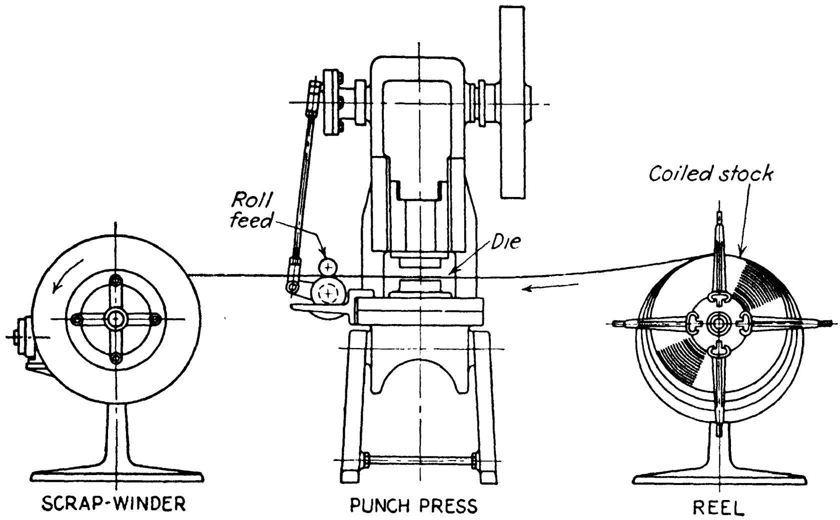


FIG. 144.—An indicated setup on a gap-frame press for the reel, coiled stock, die, roll feed, and scrap winder. This cut suggests ways and means for working out special setups for handling new jobs. (*Courtesy of F. J. Littell Machine Co.*)

punches and dies. Presses equipped with modern types of roll feeds need no other safety attachments.

Stock Strip Straighteners.—Figure 143 is a picture of a gap-frame press showing a pair of feeding rolls set up on a bolster plate with a stock strip straightener attached. The strip is pulled through the straightener by action of the feed rollers. This straightener is composed of five rollers, two above and three below. It is positioned between the stock reel and the feeding rolls. Some straighteners have as many as nine rolls, four above and five below. A good straightener ensures that all curvatures and bends are rolled out of the strip so that it enters the dies in as nearly a perfectly flat condition as possible. The upper rollers in the straightener can be individually adjusted and are designed to equalize their pressure across the strip.

Typical Discussion Sketch.—The drawing of a roll-feeding setup given in Fig. 144 is helpful in explaining the principles involved in these

types of press feeds. Here we see all the necessary units laid out in sequential order. The only members missing are a stock strip oiler and straightener, and these are usually inserted between the reel and press.

Heavy-duty Roll Feeds for Munition Items.—The large heavy equipment seen in Fig. 145 is shown handling heavy coiled steel stock

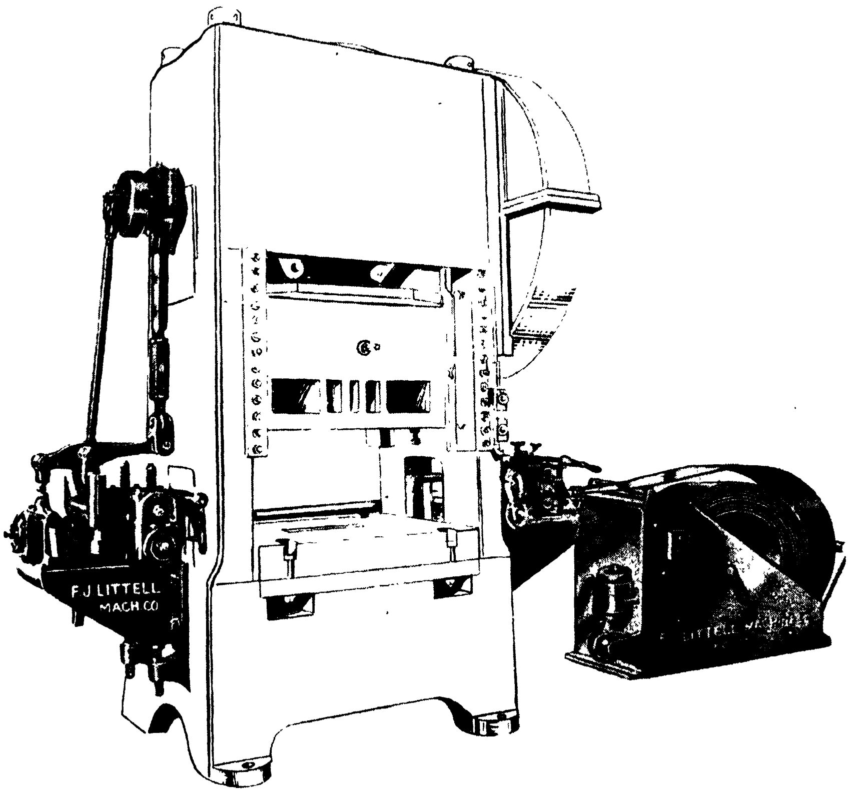


FIG. 145.—A heavy-duty double-roll feed with straightening rolls and scrap cutter mounted on a straight-sided double-crank high-speed press.

in the production of automotive, hardware, and various munition parts. The press is a large straight-side double-crank type. The stock coil is mounted in a conveyer-type cradle reel. This reel is motor driven and is also provided with an automatic loop control. When using a loop control of this type, the feed always pulls the stock from a free loop.

Straightening rolls are seen mounted at the right, and feeding rolls at both the right- and left-hand sides. The scrap cutter is shown at

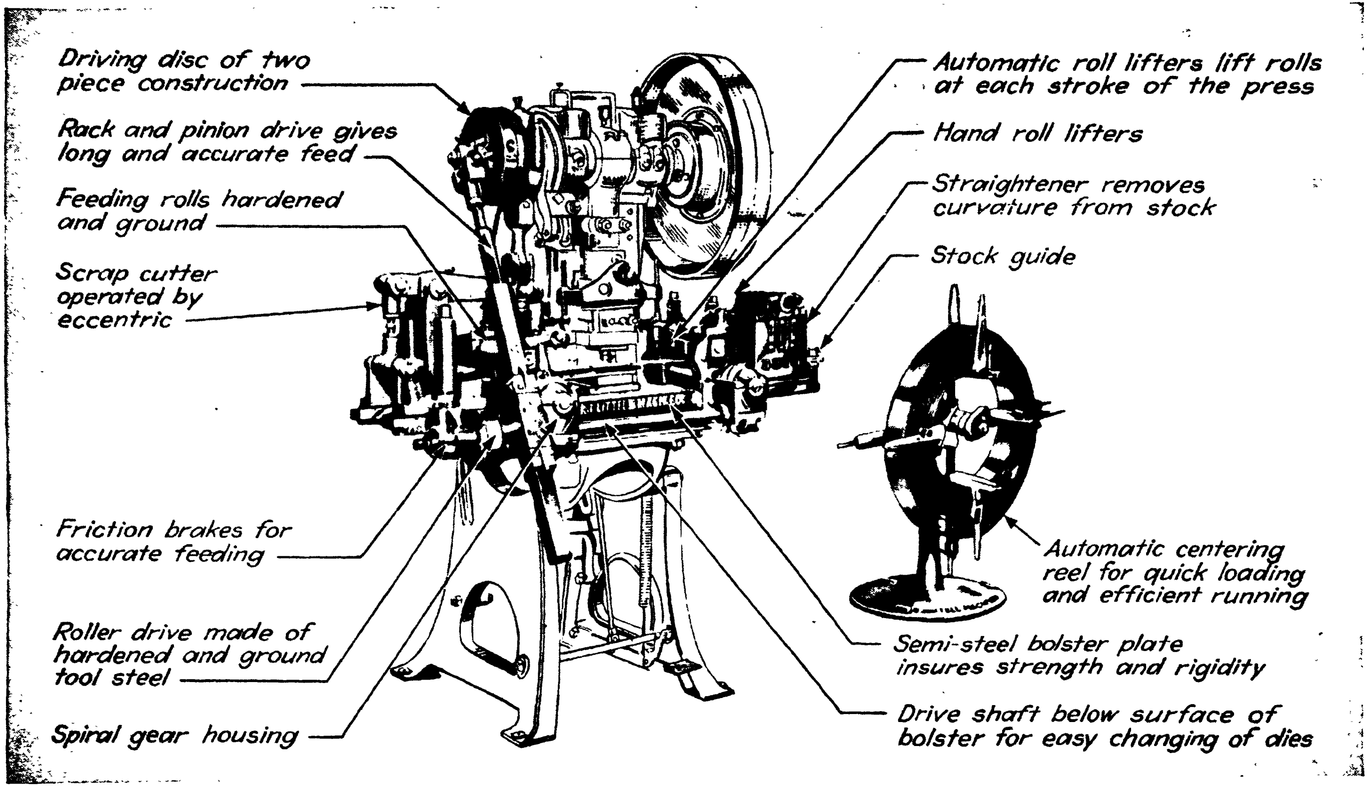


FIG. 146.—A double-roll automatic feed set up on an open-back gap-type inclinable press. Among its useful features are rack-and-pinion drive, seven-roll ball-bearing straightener, eccentric-operated scrap cutter, and standard automatic roll lifters.

the extreme left. It is operated by the rocker arm over it, which, in turn, is actuated by an adjustable rod connection shown attached to an eccentric on the crankshaft. Notice that this equipment is mounted on adjustable brackets on either side of the press. This feature is useful in taking care of the varying heights of different dies. The feed rolls release their grip on the stock at the instant that piloting takes place in the dies. The straightener causes the finished blanks to be flat, and the scrap cutter chops the scrap frame into short lengths which are easy to handle.

Double-roll Feeds.—This feed is seen set up with its necessary equipment as illustrated in Fig. 146. Here we see a double-roll feed mounted on its own bolster plate in an open-back inclinable gap-frame press. This setup is intended for the general stamping shop having many different jobs to be run in the same press.

Comparative test runs between an ordinary hand-fed press and one having double-roll feeds revealed the following facts in favor of the latter. The work produced was blanking and drawing curponickel bullet jackets. With the press equipped with double-roll feeds, one man could tend several machines. The hand-fed output was 30,000 in 10 hr., but the double-roll press produced over 57,000 finished parts in the same time. This difference was practically enough to save the expense of running one press and paying one man.

Double-roll feeds can be used on any type of gap-frame presses above No. 3 size. They can feed metal strips up to 500 ft. per minute and more for narrower strips. However, any slight deviation in the feeding distance for which the rolls are set is cumulative, and we find ourselves eventually having too much scrap or else cutting into the hole left by the previous blank. This shows the need for the roll relief with which this equipment is provided, which allows pilot punches to register in one or more holes of the work before blanking. Some of the old types of roll-feeding devices fed the rolls by a ratchet, but most of the present-day roll feeds are equipped with rack-and-pinion drives, which are a decided improvement. Some roll and dial feeds have friction drives, and these are said to be just as positive and accurate as any other type of drive.

Power Straightening Machines.—For large heavy-duty work, these roll straighteners are built in a variety of styles and sizes. The lighter ones are fed from a centering reel while the heavier are supplied with sheet stock from a large coil cradle built in as an integral part of the machine. (See Fig. 147.)

This straightener is equipped with a variable-speed drive, 6 to 1 ratio. It is fitted with a five-roll straightener, driven by a 2-hp.

motor in connection with the lower rolls. The upper rolls are ball bearing and independently adjustable; they also equalize their pressure across the strip. They are provided with a lifter so that the rolls can be elevated for starting a new strip.

Power-driven straighteners of this type provide a free loop of strip entering the straightening rolls, which is constantly maintained

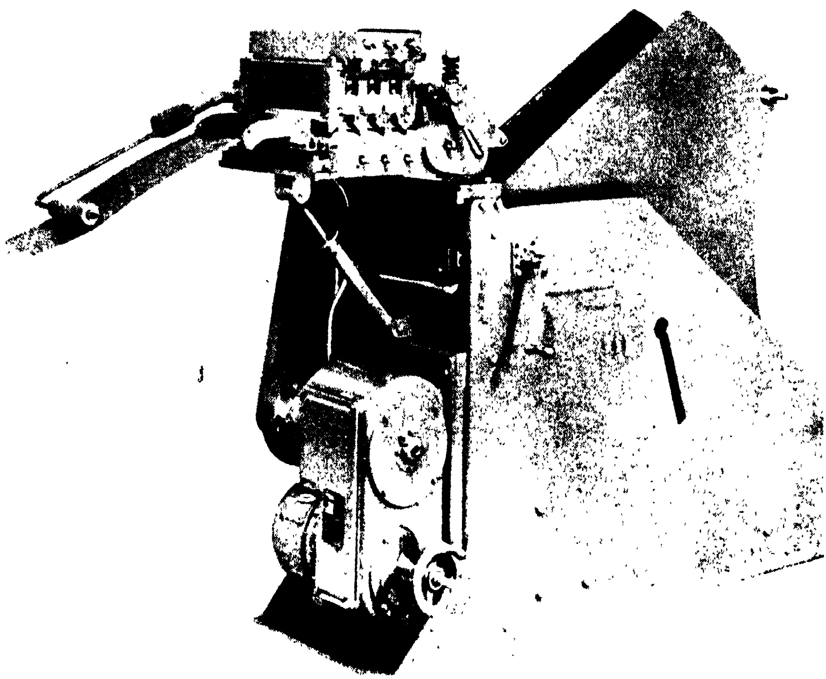
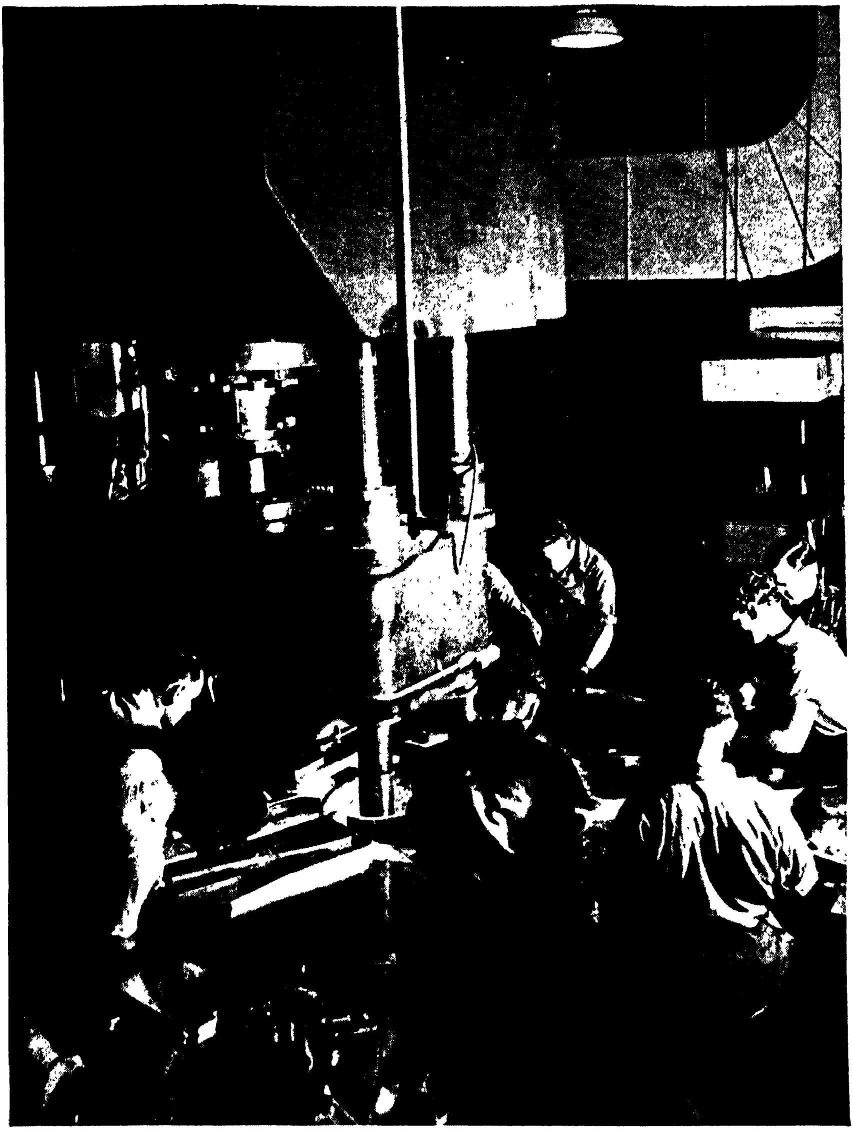


FIG. 147.—Heavy-duty power-driven straightening machine with coil cradle built in as an integral part of the machine.

by the automatic action of a special switch that controls the loop and motor. At the extreme left, and over the strip, is seen a roller mounted, on a control arm. This arm governs the amount of loop between the press and straightening rolls. It is so arranged that if the press is stopped, the loop will "run down" a certain distance and then automatically stop the reel. When the press is started, it uses up the loop, which, in turn, starts the reel again. This feature makes the entire equipment a fully automatic machine. The capacity of the coil cradle is 2,000 lb. The machine takes strip up to $\frac{3}{32}$ in. gage by 12 in. wide.



(*Ewing Galloway Photograph.*)

PLATE II.—Short cuts in warplane production. A 250-ton single-action hydropress with a rotary table that fabricates more than 20,000 parts in an 8-hr. day. Six operators are assigned places around the table. After each man has placed one or more small parts in the die on the rotary table as it "wheels" past him, the table is revolved one notch at a time until eventually all the dies and the parts they are to assemble are pressed under the powerful "hoof" of the hydropress. The machine shown here costs only about one-third as much as a larger press, but it turns out twice as much work with less than half the man power. The parts being assembled in this Lockheed plant, at Burbank, Calif., are for U.S. Army P-38's and the Hudson bombers for the R.A.F.

CHAPTER IX

DRAWING SHELLS

Introduction.—Back in the late sixties, the plasticity of metals was only a theoretical subject, simply a debatable theory. Engineering took no account of the fact that cold metals could be squeezed into new forms by forcing them into a condition of plastic flow in high-powered presses. Neither was there any practical knowledge or experience available for blanking, drawing, and redrawing of metal shells in quantity production. Light shells had to be spun, and some of the heavier ones turned on a lathe from solid metal. Shallow formed parts were hammered out in bench dies, and foundry castings were made for deep "cupped" forms and then machine finished. Then someone discovered that blanking and drawing of cylindrical shells from sheet metals was a commercial possibility. This discovery greatly increased the output of rolled sheet metals for many different gage sizes. It further encouraged the building of new types of sheet metalworking machinery.

In 1882, Bliss and Williams, Brooklyn, N.Y., brought out a "walking-beam" type of power press. It was designed to operate at a speed of eight strokes per minute. This machine ushered in a new day of progress in the pressworking of metals. If we compare this press with some of the recent types of high-speed roll-feeding machines, which produce thousands of multiple blanks per minute, it reveals one of the extremes in today's progress.

Plain Drawing Dies.—Three stages in producing a cylindrically drawn shell are shown at *A*, *B*, and *C*, in Fig. 148. At *A*, the blankholder has descended ahead of the punch, and the spring pressure behind it holds the blank taut, while the drawing punch continues to descend and pushes the blank into the die, thus forming up a shell around the punch; this is a clear case of forced plastic flow.

In drawing deep shells, the metal is forced to take an increasingly higher degree of plastic flow the deeper the punch descends. At *B* the shell is shown "cupped" into the die, and the operation is about half completed. The air vent hole through the punch prevents vacuum resistance when stripping off the finished shell.

In single-action presses, pressure on the blankholder plate depends upon compression springs, soft rubber, and, in some very large dies

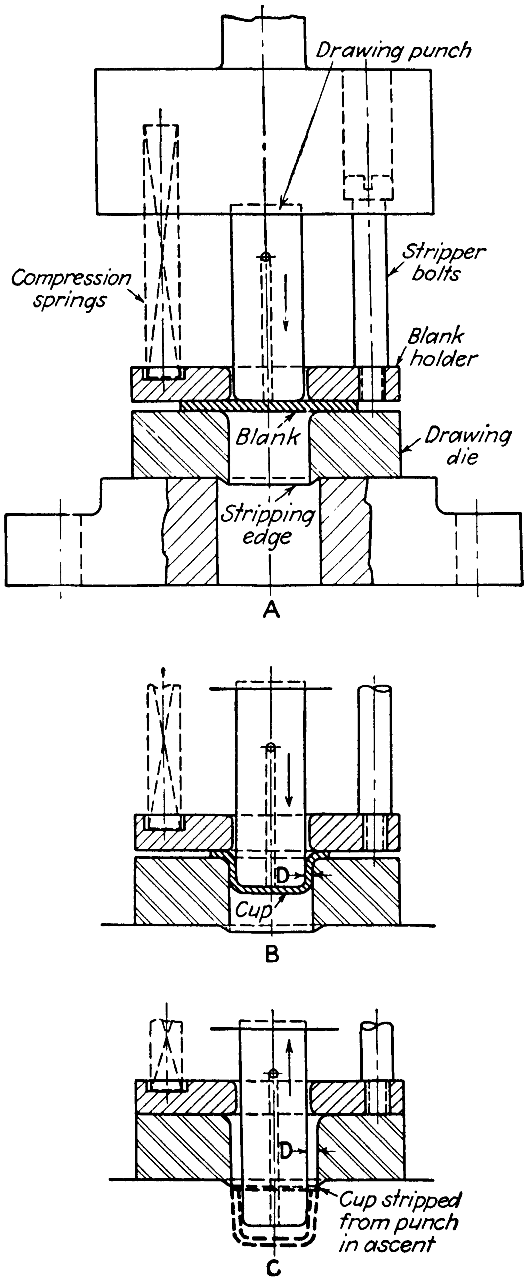


FIG. 148.—Illustrating the principles involved when cylindrical shells are produced in plain drawing dies.

and presses, hydraulic pressure. With a hydraulic blankholder, blank-holding efficiency is greatly increased. A hydraulic blankholder permits accomplishing deeper and better draws, and they are easier on the press because, unlike springs or rubber, the pressure is constant.

In a double-action press, the blankholder is attached and operated on the face of the outer ram. The outer ram descends ahead of the

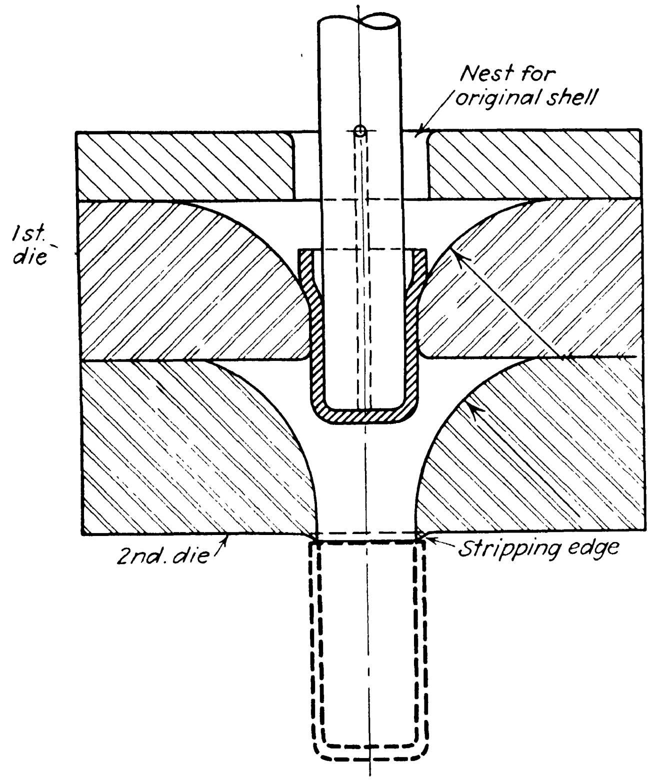


FIG. 149.—Ironing, reironing, and thinning the walls of cartridge cases by drawing them through double-reducing die blocks.

drawing punch and holds the blank taut while the punch descends through it and draws the shell into the die.

Clearance D is the same as the thickness of work material; it is a uniform space that extends all around between the punch and die. This space is sometimes made a few thousandths of an inch less than the material thickness for "ironing" the shell wall thinner.

At C, the punch has pushed the finished shell through the die and has begun to ascend. The mouth of the shell has expanded slightly and cannot reenter the space through which it was drawn; when the

ram ascends, the shell is therefore "stripped" from the punch against the circular stripping edge shown under the die.

Ironing Cartridge Cases without Using Sleeves.—Figure 149 illustrates the process of performing two ironing reductions on cartridge-case walls at one station. The thickness of the second die block must be sufficient to permit the operation in the first block to be completely finished before the nose of the shell enters the second die. If this is neglected, the shells will be torn, because of a double pull on the metal surrounding the nose on the punch.

First, the original shell is held vertically in the "nest" shown attached over the upper die block. The shell reduction in the first block should be the maximum amount that will not cause wrinkles when no "sleeve" is used around the punch. Reduction in the second block should not exceed 8 to 10 per cent of the wall thickness, depending upon the kind of metal used, its annealed condition, and the size or diameter of the shell.

Materials Used for Cartridge Cases.—Cartridges made from brass stock, admiralty metal, or preferably "cartridge brass" are composed of 68 to 70 per cent of copper and 30 to 32 per cent of zinc. "Pure Lake" or "Electrolytic" grades of copper are specified 99.88 per cent pure, the remainder being small quantities of lead and iron. The zinc used is specified as "Grade A"; Brinell hardness for No. 12 Brown & Sharpe gage (0.0808-in.) brass strip should test between 50 and 65. Admiralty metal is practically the same alloy as cartridge brass, being 70 per cent of copper, 29 per cent of zinc, and 1 per cent of tin, while cartridge brass is a 70–30 mixture of copper and zinc.

USING SLEEVES FOR REDRAWING SHELLS

The Functions of Sleeves.—What is a redrawing sleeve? A redrawing sleeve is known to some die engineers as a "hold-down." Under either name, a sleeve or hold-down, it may serve three separate or combined functions.*

1. To hold the shell to be redrawn straight in line with the die, as seen in Fig. 152. This function could be served equally well by using a "nest" secured on top of the die block, as shown in Fig. 151.

2. A sleeve prevents the shell from being drawn crooked or bent over its axis.

3. It makes it possible to obtain a larger shell reduction without wrinkling, because it furnishes a high "pull-back" pressure, as follows: (*a*) From the outside corner, at *R*, which acts like an internal die.

* Waterbury Farrel Foundry & Machine Company, G. W. Jackman, die engineer.

(*b*) From the actual "pinch" between the end of the sleeve and the face of the die, which puts pressure on the shell between those parts. The pinch can be applied either by spring or cushion pressure, as shown in Fig. 152, or by the conventional blankholder pressure as used in a cam-actuated double-action press.

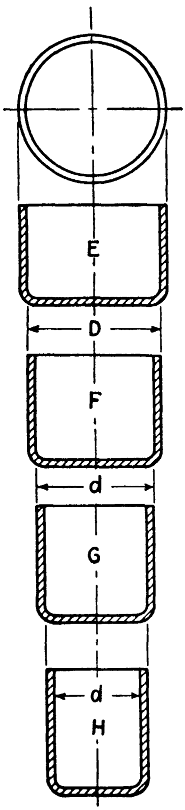


FIG. 150.—A series of consecutive reductions made in the diameters of cylindrical shells by redrawing them.

Avoiding Wrinkles.—An initial tendency to form wrinkles is always present in any drawing operation. This is due not only to the unconfined metal at the point where drawing and "flow" begins, but also to the compression caused by reduction in the perimeter of the shell, which in turn has a tendency to thicken the metal. Wrinkles are prevented by producing a counteracting tension force at right angles to the above-mentioned compressive force; this will maintain a "balance" and keep the metal at the same thickness, thus avoiding wrinkles. It is this tension effect that causes the metal to flow straight into the length of a shell, rather than "build up" its wall thickness and start wrinkling.

Tension, or "back pull," is caused by the resistance of the metal to change from a larger to a smaller diameter, and it can be produced by the following conditions:

1. The sharpness of radius *R* on the drawing die corner. A small radius means more friction under the metal and less wrinkles, but it is limited by the tensile strength of the shell being drawn into the die. The thickness of metal also governs the size of the radius.

2. Radius *R*, on the sleeve, is governed by practically the same remarks as given for the die radius above.

3. The amount of pressure on the sleeve will also prevent wrinkles, but it is also limited by the tensile strength of the shell walls.

4. Experience has taught that a radius of about twice the metal thickness can safely be used for *R* when redrawing shells as in Figs. 151 and 152.

Sizes of Drawing Radii.—Although there is a fairly definite relationship between the blank thickness and drawing radius *R*, the radius should be varied for large blanks and different tempers of metals. However, for drawing ordinary blanks, the following sizes for *R* have been taken from practice.

For $\frac{1}{64}$-in. stock, use $\frac{1}{16}$-in. *R*. For $\frac{1}{32}$-in. stock, use $\frac{1}{8}$-in. *R*. For $\frac{3}{64}$-in. stock, use $\frac{3}{16}$-in. *R*. For $\frac{1}{16}$-in. stock, use $\frac{1}{4}$-in. *R*. For $\frac{5}{64}$-in. stock, use $\frac{3}{8}$-in. *R*. For $\frac{3}{32}$-in. stock, use $\frac{7}{16}$-in. *R*. For $\frac{1}{8}$-in. stock, use $\frac{9}{16}$-in. *R*. These figures apply to drawing shells from a blank, and if *R* exceeds these figures excessively, the holding

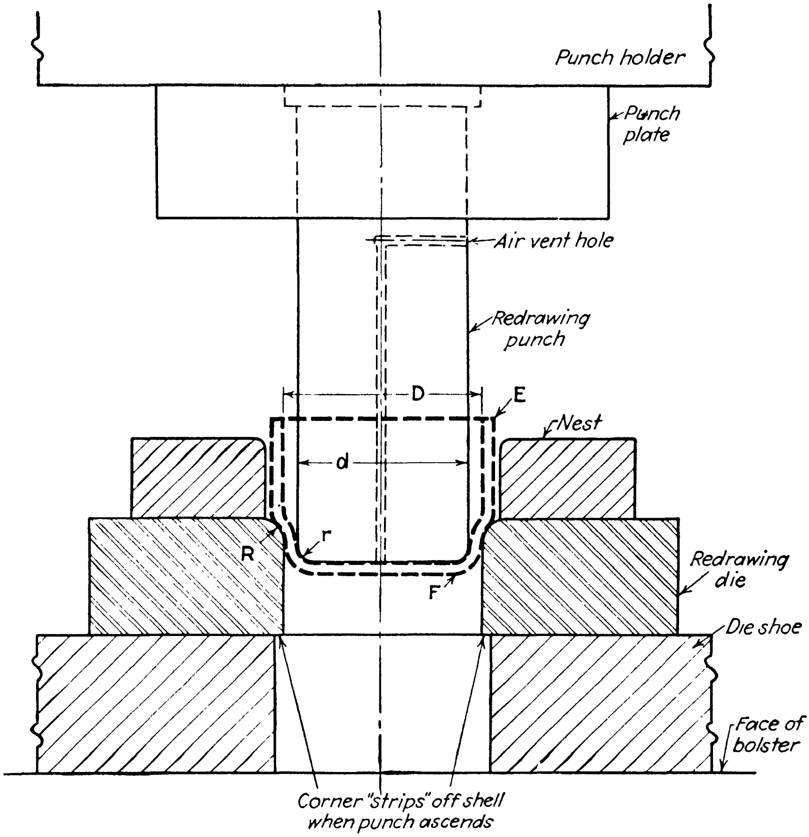


FIG. 151.—A simple redrawing die in which the cylindrical shell to be redrawn is "centered" in a "nest" attached to the die block. No redrawing sleeves are necessary in dies of this type if the difference between *D* and *d* is not very great.

tension on the blank cannot be adjusted to prevent wrinkles in the stock when it is drawn over the radius. On the other hand, when *redrawing* shells these radii can be reduced, in some cases, more than half.

If the radius *r* on the face edge of the punch is equal to or greater than *R*, so much the better. Of course much depends upon the kind of material being used and most of all upon its deep-drawing qualities. If in doubt, most toolmakers will make up an experimental tool and determine the sizes of drawing radii for the proposed material.

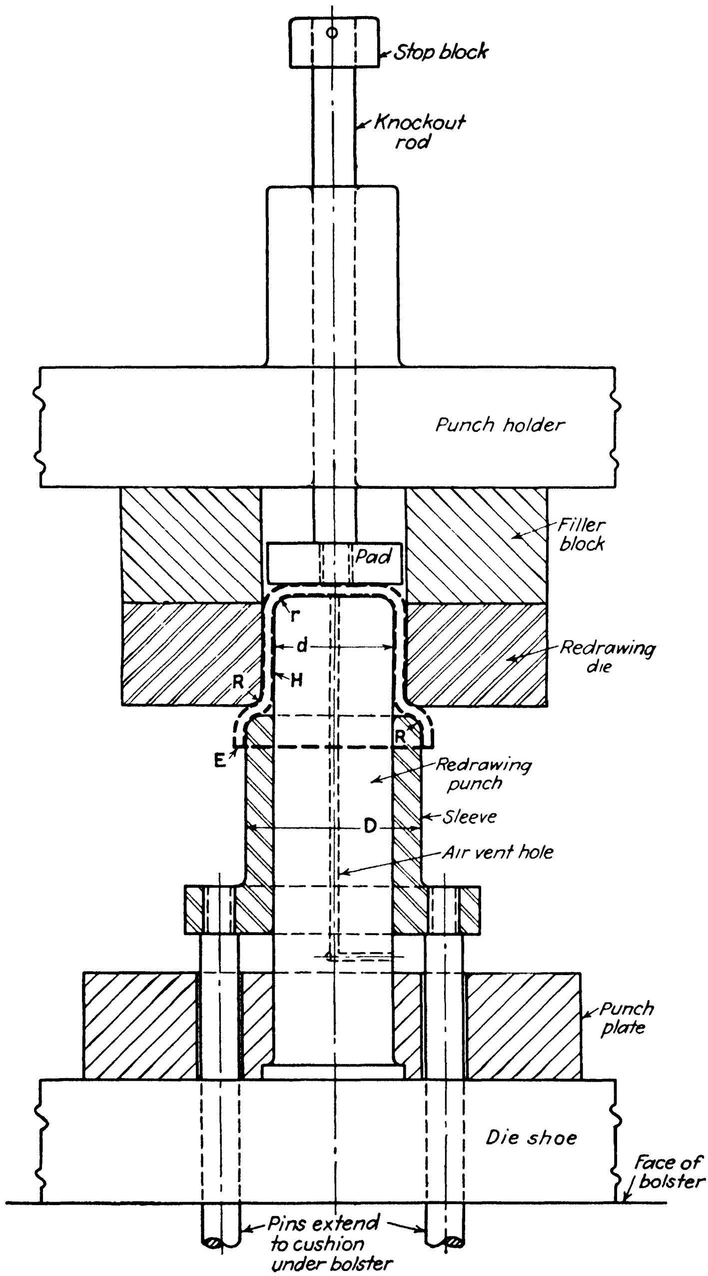


FIG. 152.—A typical redrawing die in which a sleeve is used for making a maximum reduction in diameter when redrawing cylindrical shells.

When to Use Sleeves.—One of the first questions that arises on a new redrawing job is whether or not to use a sleeve. The answer to this question depends largely upon the following conditions.

1. The ratio of the thickness of the metal to the diameter of the shell. Sleeves are very likely needed if the diameter of the shell exceeds fifteen to twenty times its wall thickness.
2. The percentage of the shell reduction made.*
3. The kind of material being used.

It is the usual preference not to use sleeves if it is possible to avoid them, because of the mechanical complications involved in building the die. If by adding more operations we can avoid using sleeves, this procedure is considered better. When running a redrawing job on a multiple-operation machine, reducing the number of operations is usually of no benefit; in fact, it can frequently be the contrary.

Sleeves have been used on multiple-station redrawing jobs approximately as follows.

1. Beer can 4¾ in. long, 2½ in. diameter, 0.010-in. sheet steel.
2. Flashlight case 6 in. long, 1½ in. diameter, 0.018 in.-sheet steel and brass.
3. Aluminum tube 4½ in. long, ½ in. diameter, 0.020 in. gage.

Other jobs have been run, using 0.015- to 0.020-in. brass, aluminum, and steel, in which no sleeves were found necessary. There are no fixed rules to follow, unless there is a precedent or a similar job which has been previously run. The "tryout" can usually start with about a 15 per cent reduction in diameter, and if this works out experimentally, there will be no trouble whatever in the multiple-station machines, because the metal "warms up" and is then in better condition for redrawing.

Analyzing Tool and Operating Cost.—In Fig. 150, we start with the first operation shell shown at *E*, while at *H* is shown the diameter and height of the proposed finished shell. We are now at the "crossroads," where one is likely to go astray. Someone may propose that if we made a series of three redraws, as at *F*, *G*, and *H*, in which the shell reduction is only twice the thickness of the wall, in each of three dies, no sleeves would be necessary, and this would be a good procedure to follow. The proposed redrawing die is the type shown in Fig. 151.

We admit that this would be right if the necessary machine equipment is at hand and if the shell walls are heavy-gage material. The proposal would work out all right if a multiple-station machine is

* If D is the larger shell diameter and C the smaller, then $(D - C)/D$ is equal to the percentage of shell reduction.

used, but if the shell gage is thin, too many redraws would be necessary in order to lead down to the final reduction of diameter.

On the other hand, to build and use three separate operation dies would increase the tool, labor, and material-handling costs perceptibly. Again, the number of single-operation dies needed, if the shell gage is thin, would result in tool, labor, and manufacturing costs approaching astronomical figures.

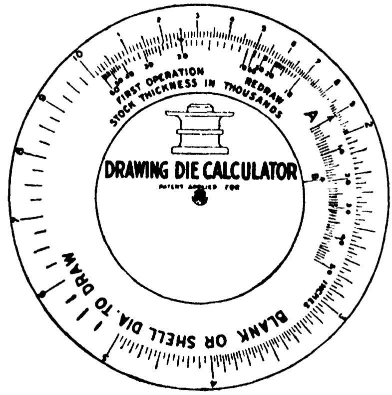


FIG. 153.—Revolving dials are employed in this circular slide rule for determining correct reductions of diameters for drawing and redrawing cylindrical shells.

Redrawing Die with Sleeve Attached.—Figure 152 is a sectional view through a central vertical plane showing a redrawing die with an attached sleeve, and its indicated operation. This tool redraws shell *E* to shell size *H* in one easy operation. Shell *E* is an easy sliding fit over the outside diameter of the sleeve. The shell is placed in position when the sleeve rises flush with the nose of the punch on the upstroke of the ram. When the die descends, it redraws and reduces the shell interior to the diameter of the punch, while the sleeve depresses and permits the metal to "flow" over its nose and up into the die. It is impossible for the shell to form wrinkles because the nose on the sleeve at *R* exposes no uncontrolled metal at any time.

As the die ascends, after redrawing the shell as indicated, an air vent hole through the punch permits the completed shell to be carried up within the die. A knockout rod contacts a bar through the head of the press and ejects the shell near the maximum ascent of the ram. The press being tilted back, the work falls into a container at the rear of the machine. Another shell is then placed over the sleeve, and the cycle is ready for repetition.

Calculating Shell Reductions by Slide Rule.—A convenient circular slide rule, made of celluloid, is now available for quick calculation of the correct reduction of diameters, when redrawing shells of different gage thicknesses.* A representation of the instrument is presented in Fig. 153. It consists of three "centered" disks, which can be revolved. Arrow *A*, shown on the middle disk, is pointed at graduation marks on the outer disk, which indicate the diameter

* General Motors Corporation, Ternsted Division, Detroit, Mich. Otto H. Jensen, mechanical engineer.

of the original shell. Next, arrow *B*, on the inner disk, is pointed at the same diameter on the middle disk. The correct shell diameter for the first reduction can then be read over "stock thickness in thousandths," among the graduations found on the outer disk. There are several other useful features combined in this calculator.

DRAWING AND REDRAWING SHELLS WITHOUT WRINKLES

If the Metal Is Not Closely Guided and Confined in Drawing Dies, While Being Forced to Take Other Shapes, Wrinkles Will Form

Cause and Cure of Wrinkled Shells.—The primary cause of wrinkles in shells is the movement of uncontrolled metal. Somewhere during the drawing interval—if the die has been improperly designed—this uncontrolled metal has a chance to "fold" instead of being made to "flow," and then the wrinkles will appear.

When turning a shell inside out, the material is drawn over a radius by the punch descent. The size of the drawing radius is usually between four and five times the thickness being drawn. The punch pulls the metal from under the blankholder and redraws the shell down into the die. In this procedure the movement of metal is under constant control while it is being transformed into another shell of different size and shape. An illustrated description of a redrawing die for these types of operations is shown under the subject of the "inside-out" method for redrawing shells (see Fig. 157).

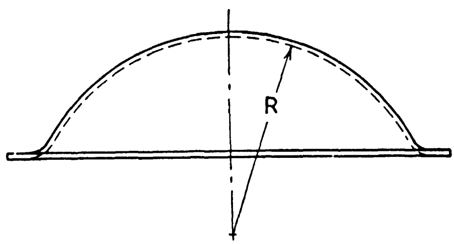


FIG. 154.—A first operation circular shell that is drawn similar to a spherical segment in form but of a more elongated section is the most convenient shape to use for redrawing into many types of shells.

A Method for Shallow Drawing.—In drawing and redrawing certain cross-sectional shapes of shells, there are several methods resorted to that tend to avoid the formation of wrinkles. For example, a first operation shell can be drawn similar to the shape of a spherical segment, or "dished," as a diemaker would say. (See Fig. 154.)

In the second operation the concave portion of the dish is redrawn by the punch that enters within the shell. The ram descent causes the punch to draw the work up into a die mounted on the punch holder.

This type of operation is illustrated in Fig. 155. The principal use of this method is for shallow redrawing. It is used for the redrawing

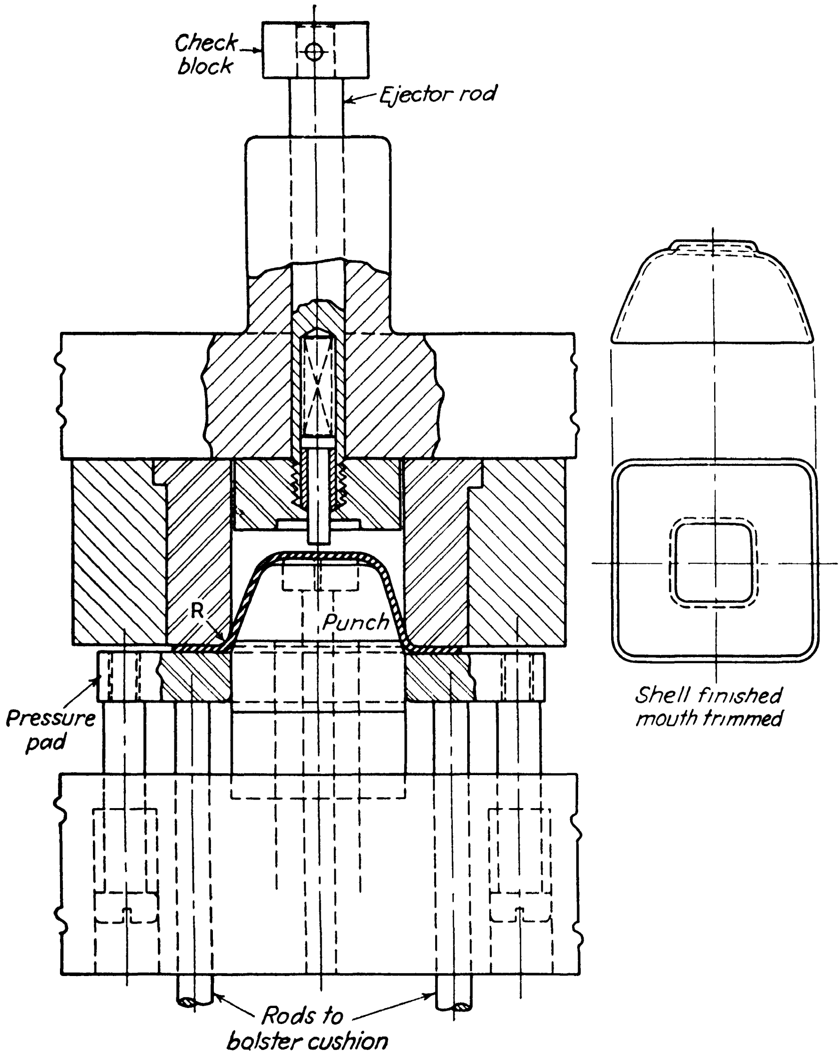


FIG. 155.—An inverted redrawing die in which the first operation shell (Fig. 154) is placed mouth down over the punch and on the face of the pressure pad. When the ram descends, the shell is depressed with the pad, and in this manner the shell is brought into contact with the punch while the redrawing die is over it. As the ram continues to descend, the shell is redrawn up into the die as indicated. This die redraws a square shell with round corners and tapered sides as illustrated at the right.

of depths that are about the same as the height of the dish, but for shapes that are different than the dish.

Difficulties in Drawing Spherical Shapes.—Contrary to what we may suppose, first operation spherical segments and semispherical shapes—as shown in Fig. 154—are difficult shells to draw free of wrinkles. This is especially true if we attempt to use a steel blank. A die in which a nonferrous shell of these types can be successfully drawn will fail utterly when a steel blank of the same size and thickness is substituted. The steel shell will show plenty of wrinkles.

The reason for this is that the slope of the drawing radius necessarily leads into the die too obtusely. The metal is not forced to turn abruptly into the die, which is necessary to set up plastic flow within the blank. The ideal condition for producing plastic flow is when the metal is drawn over a radius of a 90-deg. angle.

Stretching Semispherical Shells.—We may be able to draw a semispherical shell by the stretching method. With the blankholder held down extra tight on the sheet, the punch descends and stretches the desired shape into the die. However, this kind of an operation produces very poor work. The shell has been seriously weakened by stretching its material beyond the elastic limit. In drawing shells by any method, and especially when the work is to be redrawn in subsequent operations, the elastic limit of the material should never be exceeded. When a shell has been excessively stretched its surface presents an "orange peel" appearance.

A Die for Drawing a Spherical Segment.—The principles set forth in Fig. 156 represent a suitable die for smoothly drawing spherically shaped shells from any metal blank of steel and even Stainless steel. The principal feature in the success of this tool is the wire ring shown in the face of the pressure pad. Without this ring the tool will fail to draw steel shells without wrinkles.

A circular groove is turned in the working face of the blankholder, or pressure pad. A steel wire is then forced around into the groove. About one-half of the wire diameter is left exposed to hold down the blank on the die face while the punch is drawing the shell. For Stainless or other varieties of steel that are difficult to handle in drawing dies, an auxiliary groove is turned in the face of the drawing die. This groove coincides with the position of the wire, as seen at *A* in the small sketch above the die. For drawing of very ductile nonferrous metals, the wire ring can be omitted.

Drawing Stainless Steels.—There are five general types of so-called "Stainless" irons and steels. The word "Stainless," when used in connection with iron and steel, is a trade name which has been registered in the U. S. Patent Office. In general, Stainless steel is composed of a mild-steel base, with 11 to 13 per cent of chromium,

about 0.25 to 0.35 per cent of carbon for hardness, a small amount of nickel, and sometimes silicon added. This material is about 25 per cent stiffer than mild steels, and therefore a lighter gage of Stainless will provide the same strength as heavier gages in ordinary steels.

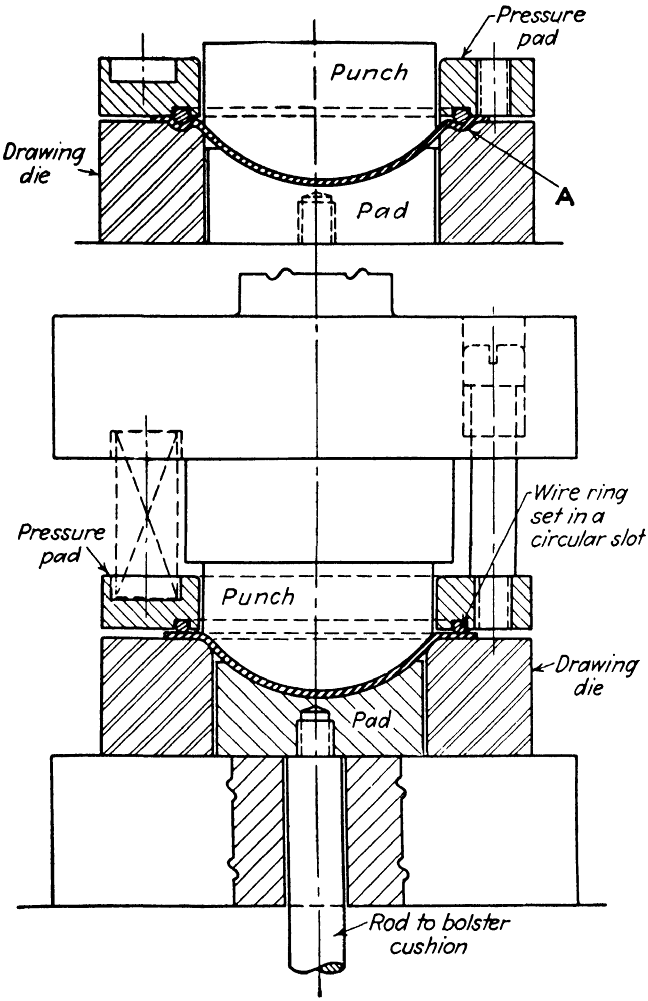


FIG. 156.—Sectional views through a die that draws a shallow spherical-segment shell from a steel blank.

As its name implies, Stainless steel is practically rustproof and resists the reactions of atmospheric changes and of many different acids, including those of fruit and vegetables. The composition of Stainless steel indicates that it cannot be machined or worked in dies so easily as mild steels. This is true to the extent that the labor cost of pro-

ducing drawn parts is almost double that for other types of steel; the wear in drawing dies is also twice as great. Annealing is necessary between each of the drawing operations, sometimes at a heat of 1950°F., and at other times only 1350°F., depending upon the severity of the draw.

Type 3, Stainless Iron No. 18, is the easiest Stainless alloy to work in drawing and forming dies, according to the Crucible Steel Co. of America. This is the type most often used. Its chemical and physical properties for the annealed state follow.

Carbon	0.07 to 0.12 per cent
Chromium	17 to 19 per cent
Tensile strength	72,000 lb. per square inch
Elongation in 2 in	30 to 35 per cent
Brinell hardness	155 to 170
Weight per cubic inch	0.3033 lb.

As the chromium content increases, these steels gradually lose their capacity to harden, and the 18 per cent chrome steels may be considered practically unhardenable. What Stainless lacks in strength, it makes up in increased resistance to corrosion. It is superior for deep-drawing operations, and for severe bends and forming complicated contours. It is used in fabricating cooking utensils, table tops, restaurant equipment, tubular articles, automobile lamps and trim, and for all parts in which strength is secondary to corrosion resistance. This type of Stainless alloy, with silicon added, is largely used in chemical plant construction, especially where a high resistance to nitric acid is desirable.

Before annealing, parts should be thoroughly sand-scoured so that every vestige of the lubricant used for drawing is removed. The lubricant, if left on the shells through annealing, forms a gritty abrasive which is very destructive to dies. After annealing, the shells are pickled in a 15 per cent solution of hydrochloric acid, and again thoroughly scoured with beach sand. The scouring is important and must not be slighted if the best possible results are expected. Do not use sulphuric acid as a pickle or for cleaning.

In finishing Stainless steel, there are usually two or more grinding operations, using coarse-grain abrasives to start with and finishing with finer grain. The shells should not be polished with powders that contain quantities of sulphur, as this mineral is injurious and will prevent satisfactory finishes. As a recompense for the excessive costs and for the many difficulties encountered in manufacturing Stainless steel products, it takes a beautiful finish, and its final appear-

ance is very attractive and desirable. It requires no polishing aftei the above finishes.

THE "INSIDE-OUT" METHOD FOR REDRAWING SHELLS

In Redrawing Shells, by Turning Them Inside Out, the Metal Is Kept So Closely Confined, That Wrinkles Cannot Start

Introduction.—Designs for drawing dies to produce new and odd-shaped parts are among the many problems that confront tool engineers who are engaged in the present war production. It is therefore well to have sketches of some standard tooling methods at hand. These sketches often point the way toward a practical solution of special tool designs. This saves unnecessary study and the time lost in attempting to produce the part in some unconventional way. For instance, there are several methods by which to draw tapered shells with round, square, oval, or other cross-sectional shapes, and it is proposed to discuss some of them here.

Tapered Shells Drawn Inside Out.—The round tapered shell shown drawn and trimmed at *A*, in Fig. 157, is produced in the redrawing die represented in the same line sketch. The first operation shell is shown at *B*. This shell is drawn of sufficient depth to provide metal for subsequently trimming off its top. It is drawn in one or possibly two ordinary drawing operations, depending on the relationship between its depth and diameter. Its bottom is of a slight convex form, and its inside diameter is a slip fit over the outside diameter of drawing die *C*.

Shapes of Shells Are Determined by Punch.—If the depth of the draw is shallow, shedder *D* is activated by a spring plate or rubber bumper under the die shoe, but for deeper shells rod *E* rests on an air cushion flush with the bolster plate. The first operation shell must be properly annealed, so that shell *A* can be taper drawn from this shell by turning it inside out. The principle involved here is, of course, that in drawn work the shape of the shell follows the contour of the punch. The sketch shows this redrawing operation about half completed.

Methods for Trimming the Shells.—It is not necessary that the free height of the shedder face come up flush with the top of die *C*. This is because the shell is tapered and therefore the ejecting movement required is very small. If the shell is large, the die is designed for use in a double-action press. The first operation shell is then used without a convex bottom; in other words, the bottom is flat. Plate *F* then becomes the blankholder and is operated by the outer ram of the press.

The length of drawing punch G is equal to the inside depth of the finished shell. Trimming ring H is made adjustable to take care of its diminished height after grinding for sharpening. The outside diameter of the trimming ring is a sliding fit within the die. When the ram descends, and the punch redraws the shell, the ring enters the die

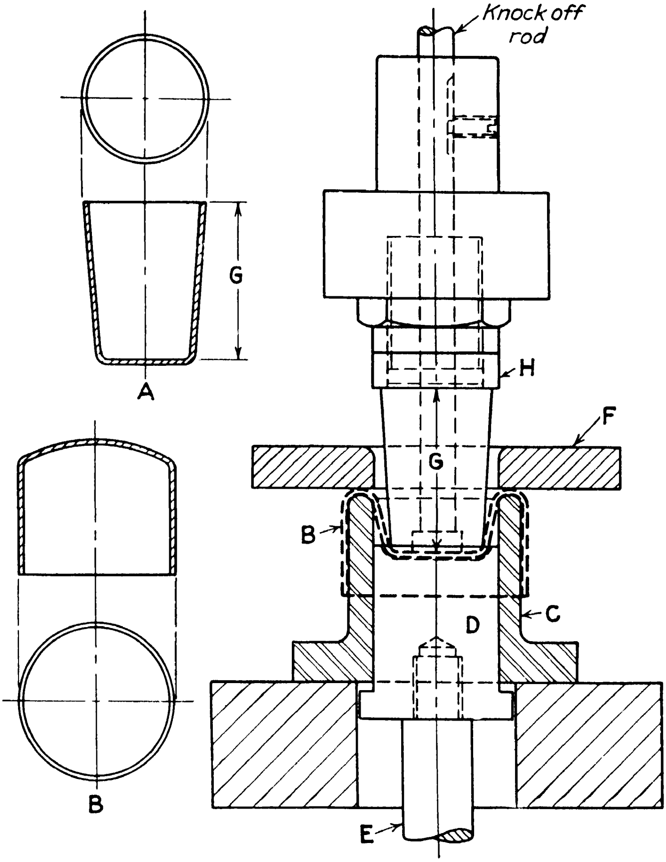


FIG. 157.—Tapered shell A is a redrawn product of the first operation shell B. In the redrawing die at the right, shell B is turned inside out to produce shell A.

and "pinches off" the irregular edge around the top. A pinched-off edge is not a perfectly square edge, but it serves the purpose in many cases. Square-edged trimming is done in a trimming lathe, by the "shimmy-die" method, or a right-angled flange is left around the mouth of the shell to be trimmed and then straightened up by pushing the shell through another die.

Avoiding Wrinkles.—The advantage in redrawing shells inside out is the easy avoidance of wrinkles. Wrinkles once started cannot be

ironed out in subsequent operations. There is absolutely no chance for wrinkles to form when redrawing a shell as illustrated and described. The metal is kept under confinement so closely that wrinkles have no chance to start.

Stripping without a Shedder.—There are cases when a shedder is not used in these dies. Instead, a "floating" split ring is provided in the die and the finished shell is forced through the ring by the punch. When the punch ascends, the ring "strips" off the shell, and the entrance of the next shell, in the die, pushes it out where it falls beneath the press.

In these types of dies, guideposts are usually unnecessary, because, if the initial setup of the tool is aligned correctly, the operation of redrawing the shells will keep the punch and die properly centered. In the sketch, a "knock-off" rod is seen which is used to "strip" the shell from the punch. This function occurs near the top of the press stroke.

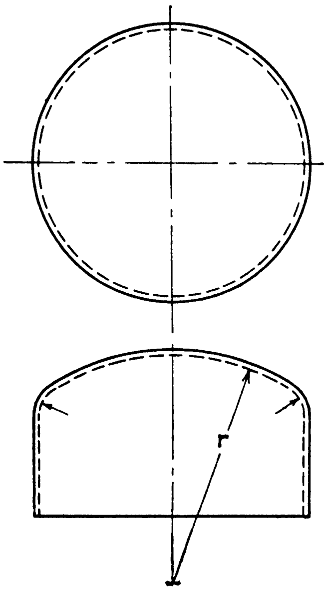


FIG. 158.—First operation drawn shell having a bulged bottom similar in form to a spherical segment, as indicated by radius r.

METHODS FOR DRAWING AND REDRAWING SHELLS WITHOUT WRINKLES

Two Methods for Redrawing Shells.—A first operation drawn shell, as shown in Fig. 158, can be placed over the drawing ring of a die as illustrated in Figs. 159 and 160. From these positions the shells can be redrawn by two entirely different methods. (1) The shell can be turned inside out by redrawing it *down* into the die as indicated in Fig. 159. (2) The shell can be redrawn *up* into an inverted die, without turning it inside out, as shown in Fig. 160.

In both cases the tendency of the shells to wrinkle is eliminated. This is because the movements of the metal are positively controlled at every stage of the operations. The method of control is as follows. The original shell has a sliding fit over the outside diameter of the drawing ring. When the ram descends, the punch forces the shell walls in opposite directions, *up* in the one case, and *down* in the other. In either operation the original shell wall slides up on the ring so closely that it cannot wrinkle. Continuing in descent, the punch redraws the shell into a smaller die, and to a different shape, while the drawing ring, by the pressure it exerts on the work, prevents the wrinkles.

In all shell-drawing operations, the die determines the direction of plastic flow, while the cross-sectional size, shape, and length of the shell follow the contour of the punch. However, if the metal is pulled out from under the pressure pad just before the end of the draw, the work does not hug the punch so tightly around its top. This feature is made use of for stripping shells from punches where the shells are pushed through the die and the shell top contacts a stripping edge under the

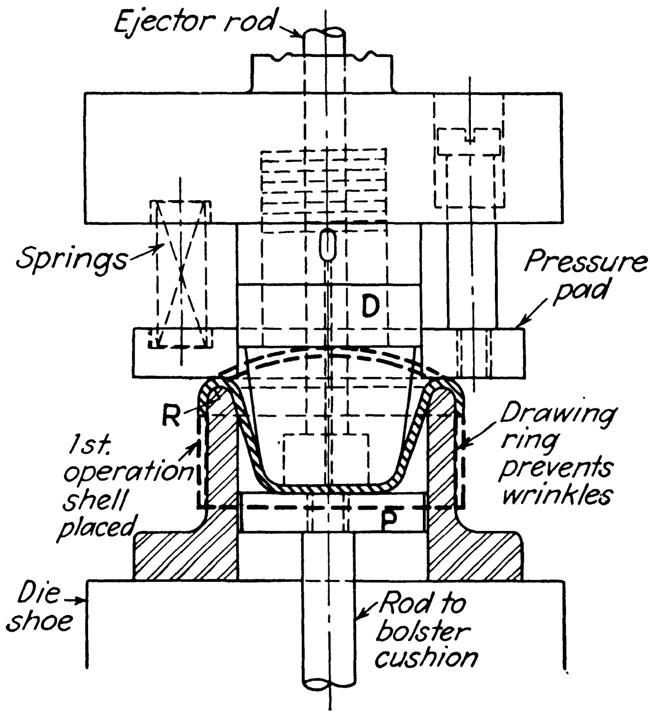


FIG. 159.—Reverse redrawing of a first operation shell. The top edge of the shell is trimmed off by ring D on the punch. Trimming occurs just before pad P "banks" on the die shoe. The work is stripped from the punch in ascent by an ejector rod.

die when the punch ascends. If this feature is undesirable, and close hugging of the shell around the top is desired, then sufficient metal must be provided for the draw so that some of it remains under the pad after the shell has been completed.

First Operation Shell.—The bottom of the first operation shell, Fig. 158, is bulged to the shape of a spherical segment. This is done if the cross-sectional shape of the redrawing punch is radically different than round, such as oval, oblong, or square, but with round corners, of course. A bulged shell bottom tends to force the metal into immediate contact with the sides of the redrawing punch when it contacts the shell bottom and continues to descend.

Sizes of Drawing Radii.—The size of redrawing radius R, Figs. 159 and 160, is usually $4t$ to $5t$, in which t is the material thickness. The radius on the nose of the drawing punch should not be much less than $4t$. A large radius along the corners of the punch is also good insurance against torn and fractured shell corners.

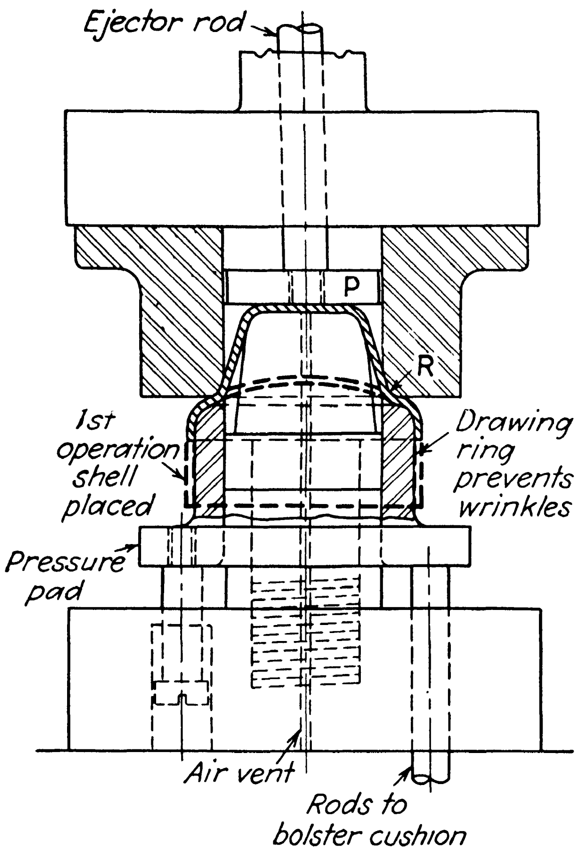


FIG. 160.—Redrawing a first operation shell up into a die over the punch. The finished shell is pushed out of the die near the top of the ram ascent by an ejector rod attached on pad P.

Percentage of Shell Reductions.—The size reduction when redrawing a shell should not be too great in any one operation. The dimensional reduction usually lies between 20 to 30 per cent of the original diameter. These reductions depend largely upon several well-known factors: (1) the kind of material used; (2) the gage size; (3) temper, annealing, and plasticity; (4) pressure-plate adjustment; (5) peculiarities in shapes and sizes of the shells involved. In the redrawing of

shells, if D represents the diameter of a shell before redrawing, and d the diameter after redrawing, the percentage of reduction is

$$\frac{D \text{ minus } d}{D}.$$

Blankholders Not Always Necessary.—Heavy-gage sizes of certain nonferrous metals, brass, and other copper alloys can be drawn to small diameters free of wrinkles, without using a blankholder or pressure pad. For such work the die opening should have more than the usual allowance of drawing radius. The resistance of a thick blank against wrinkling is greater than its resistance to flow; therefore the shell draws smoothly. In other words, we might say, "the blank is too thick to wrinkle." Light gages of metals wrinkle most. The tendency to wrinkle becomes greater as the diameter of the shell increases relative to the thickness of its wall.

Shells may be drawn without a blankholder, and with no wrinkles, if the drawing diameters do not exceed about fifteen to twenty times the thickness of the work material. The reduction ratio of the draw relative to material thickness must also be closely observed. As the wall thickness decreases, the percentage of reduction must also be decreased, and vice versa (see Figs. 164, 165).

Other Conditions That Cause Wrinkles.—As just said, there is a definite relationship between shell diameters, wall thicknesses, depths of draw, and the tendency to wrinkle. Wrinkles also seem to appear more frequently when the depth of draw is too great for the thickness of metal used. Some other conditions that cause wrinkles are too fast punch speeds and too large drawing radii at the die entrance. Plastic flow is not a very rapid process. It is better to start a drawing job at an obviously slow punch speed and then increase the speed up to all the work will take.

Analyzing Drawing Operations.—Figure 161 represents a die for drawing a first operation round shell. The punch descent is shown at a point where its full diameter begins to enter the full diameter in the drawing die. The blank has just started to draw out from the smooth surfaces between the die and blankholder. The operation is now at the stage that decides whether or not the blank will wrinkle. The critical point is at A, where the movement of metal is unconfined. At this point the metal coming in from the blank is forced into a compressive plastic flow by the punch descent. Here the metal is crowded together violently while being rapidly drawn down over the die radius in its haste to form a shell around the punch.

If the blankholder is adjusted unevenly or too loosely, wrinkles will appear around the shell. One small wrinkle may lift the blankholder enough to permit a whole "flock" of wrinkles to start folding around the work. The obvious remedy is to adjust the blankholder

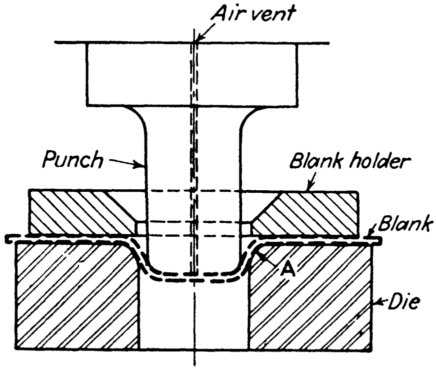


FIG. 161.—Starting the draw of a first operation shell from a flat blank.

to an even pressure. It should be adjusted to exert sufficient holding power and to cause enough friction on the "slip" of the blank to prevent wrinkles.

Angular Step on Die Face Prevents Wrinkles.—Figure 162 shows a drawing die in which an angular step, *a* deg., is seen exaggerated

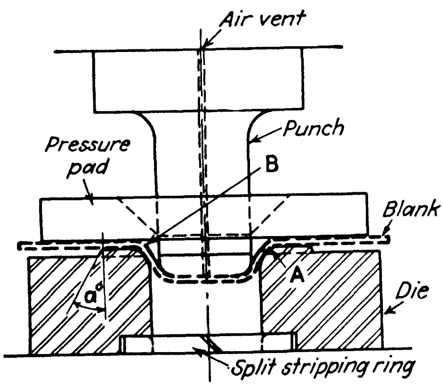


FIG. 162.—The stepped angle *a* on the face of this drawing die serves to increase friction on the "slip" of the blank, while the blank is being drawn into the die, and the holding power of the pressure pad is thus increased.

in depth below the die face. If it is found impossible to arrange the blankholder for exerting sufficient pressure on the blank to prevent wrinkles, this angle is made more acute. This will add more friction on the slip of the blank while the punch draws it into the die. This is a design often resorted to for increasing blankholder power.

Erroneous Conclusions Exposed.—There are two other features shown in Fig. 162 to which attention should be directed. The blankholder is provided with a radially edged boss *B*. The radius sweep is made to suit that of the drawing radius in the die plus the thickness of the blank. It is a mistake to think that by using this design of blankholder the unconfined movement of the metal at *A* will be protected. In practice it has been found that, when a blank starts to wrinkle, no ordinary subterfuge such as this one will stop it.

Stripping with a Ring or Latches.—Another feature is the split stripping ring shown under the die. This ring "floats" in a clearance recess between the die shoe and die. The internal diameter of the ring is made 0.010 in. less than the outside diameter of the finished shell. The shell is pushed through the ring at the downstroke of the punch and the ring then closes. When the punch ascends, the ring strips off the shell. Another commonly used stripper, in place of the ring, consists in three equally spaced latches arranged radially around the die. The latches are compressed to a stop by coiled springs. The stripping action of the latches is practically the same as the ring.

Designer Must Know Conventional Methods.—It is a convenience to have clearly in mind all the commonly used methods and operations for handling work in dies. This knowledge may often save unnecessary study and time wasted in attempting to solve a design by experimental methods in which costly failures and disappointments will be the only results.

DRAWING SHELLS WITHOUT A BLANKHOLDER

Drawing Ammunition Shells.—It is sometimes the best practice to draw certain types of shells and sizes of wall thicknesses without using a double-action press and its conventional blankholder, or without a blankholder for dies used in a single-action press. Cylindrical shells and several other common cross-sectional shapes are so produced, and the final results are excellent.

This method is used in the manufacture of ammunition cartridges, shell cases, and other cylindrical shapes in which the shell walls must be of less thickness than the bottom. This is a very good way to "iron" the walls of shells thinner, while drawing cupped shells.

Relation of Shell Diameter to Wall Thickness.—In drawing without a blankholder, the shells are likely to wrinkle if the diameter exceeds twenty times the thickness of the strip used. The depth of the first draw should not be greater than the shell diameter, unless the material and tooling conditions are very good. The shell diameter is

found by subtracting the thickness of its wall from the outside diameter.

Which Metals Draw Best?—Selecting the work materials must be done with care and caution. Tempers should be "dead soft." Naval and cartridge brass, and other nonferrous alloys of high copper content, are the most satisfactory metals for making such draws. Pure copper "flows" better than other metals when being drawn into shells.

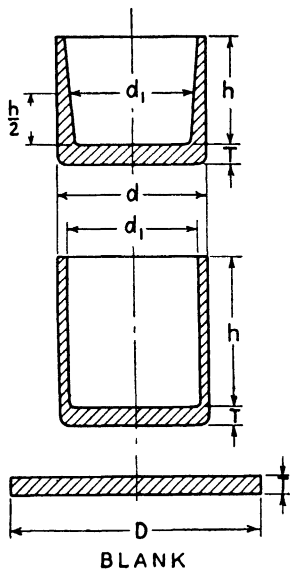


FIG. 163.—Two shells having different sections of walls—an illustration of the formulas for determining the volumes and blank diameters of the shells.

Mathematics for Ironing Shell Walls.—When ironing shell walls thinner, the wall reduction should not exceed one-tenth of its thickness, for "dead-soft" steel. For nonferrous metals one-eighth of the wall thickness is the general rule, but these figures must be reduced when the material thickness is very small. The shells should be annealed between draws, and a coating of copper or lead is considered necessary for severe redraws. The working surfaces of both punch and die should be polished in a direction parallel with that of the draw.

The mathematical conditions involved in drawing, redrawing, and "ironing" are represented by the blank and shells seen in Fig. 163. Volume V is the governing factor, and D is the blank diameter. All dimensions are for straight inches or cubic inches.

$$V = (0.7854d^2)T + 0.7854(d^2 - d_1^2)h$$

The above formula gives the cubical inch contents in either of the shells.

Then

$$D = \sqrt{\frac{V}{0.7854T}}$$

Preventing Shell Wrinkles.—Figure 164 shows the ring of a drawing die for producing a cupped shell without using the conventional blankholder. The punch has descended on the blank just far enough to start plastic flow. It will be seen that the blank is too thick to wrinkle, and this is the important factor when drawing shells without a blankholder.

Figure 165 shows this draw being completed. The shell has now been forced, by the ram descent, to "flow" up around the punch, the

plastic flow interval has passed, and the shell wall has built itself up to a height determined by the cubic inches in the blank that remained above the nose of the punch. The finished work hugs the punch closely, while the punch, continuing to descend, pushes the shell through the die. The shell is "stripped" from the punch under the

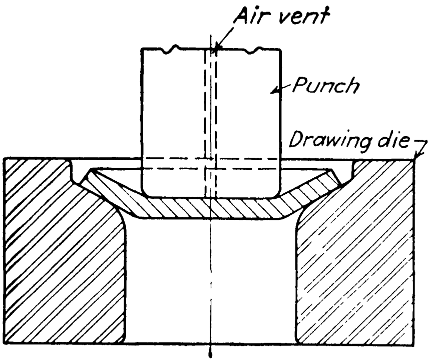


Fig. 164.—Punch in descent, "centered" over a blank and starting to draw a cupped shell into a die without using a blank holder.

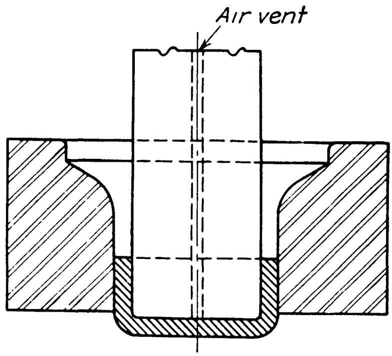


Fig. 165.—Finishing the cupped shell started in Fig. 164.

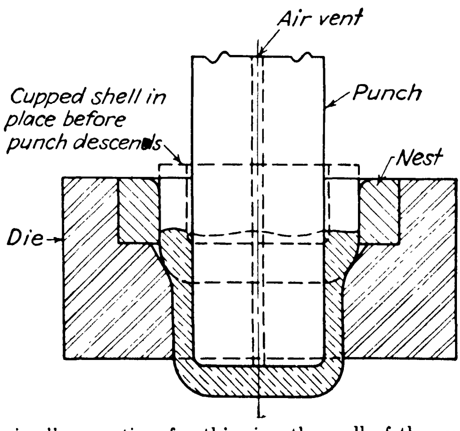


Fig. 166.—An "ironing" operation for thinning the wall of the cupped shell produced in Fig. 165. The shell is "centered" in a "nest" before the punch descends.

bottom of the die when the punch ascends. An air vent hole shown through the punch permits the shell to strip off easily.

The Mechanics of Ironing Shell Walls.—Figure 166 shows the cupped shell produced in Fig. 165 going through an operation that "irons" its wall thinner. The shell before redrawing is seen dotted in its place when the punch is up. It is observed that the punch diameter is almost as large as the interior of the cupped shell. This

prevents the formation of wrinkles while the shell is entering the reduced diameter in the die.

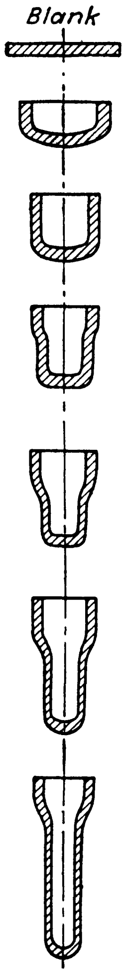


FIG. 167.—A blank and six "ironing" operations, illustrating the principle of thinning the shell walls for deep-drawn cartridge cases.

Figure 167 indicates the possibilities of shell-wall reductions when carried through six die operations. Attention is directed to the fact that, in stretching out the thin walls, a limited flow of metal is supplied by the thick walls at both the top and bottom of the shell. The heavy part at the top can either be "pinched" off in the last die operation, or, for a smoother job, it can be turned off in a shell trimming lathe.

DRAWING AND REDRAWING OBLONG SHELLS

The Last Drawing Die of a Series Is Made First.—In a manufacturing sequence of blanking and drawing operations, the last die to be used is made first, but the first die used is made last. The reason for this paradoxical situation is the fact that, in making the final drawing die first, the necessary number of drawing operations is indicated by the appearance of the trial samples produced. At the same time, the blank size and its contour can be experimentally determined. From these data a template is made for working out the interior shape of the die opening for the first operation blanking tool. So, oddly enough, the construction work for a set of blanking and drawing tools is actually done in reverse order.

Specifications of the Work.—Figure 168 represents an unusually long, deep, and narrow shell to be blanked and then drawn in two consecutive die operations. The work material is 0.0625-in., "dead-soft" deep-drawing steel, designated S.A.E. 1010. The blanking die is simply a single-station tool, not shown, but the shearing width of the strip therefor is A plus $\frac{1}{4}$ in., as seen in Fig. 169.

Advantages of Inverted Drawing Dies.—Both drawing dies, Figs. 169 and 170, are inverted types, that is, the die block is attached on the face of the punch holder, while the punch itself is attached directly and symmetrically under the die on the shoe, as shown in the two sketches mentioned. The advantage in using inverted drawing dies is the ease and speed in placing a previously drawn shell over the pressure pad that surrounds the punch and the simple and certain method of ejection, or removing the finished shell from the die.

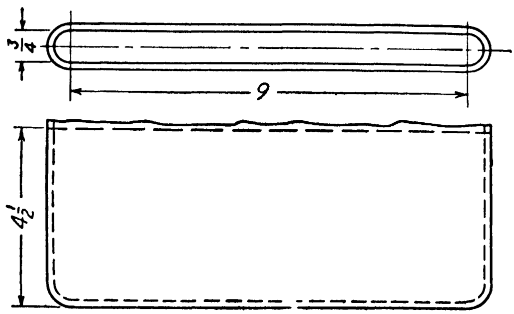


FIG. 168.—An unusual shape of shell to be blanked and drawn in three operations; an explanation of a method for square-edge trimming around its mouth is given in the text.

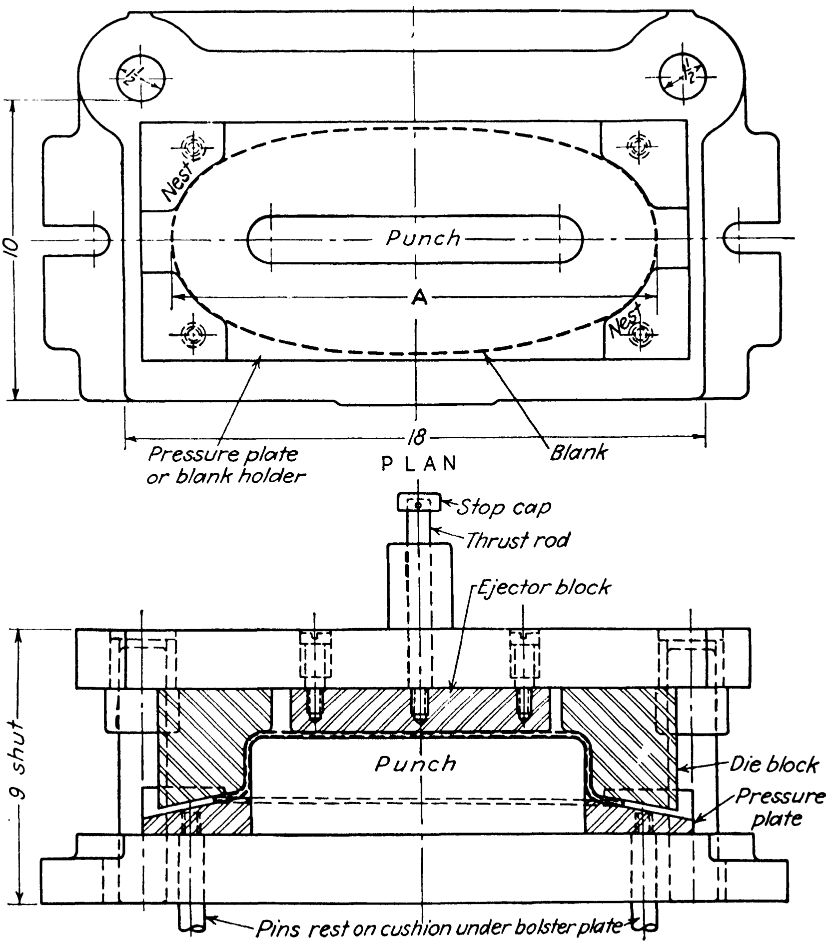


FIG. 169.—Two views of an inverted die for the first draw of the shell shown in Fig. 168.

Ejecting the Shells.—Ejection is accomplished by using a vertical thrust rod which passes through the punch shank and is attached to a block within the die. The upper end of the rod contacts the knockout bar above the press ram when the die ascends with the shell within it.

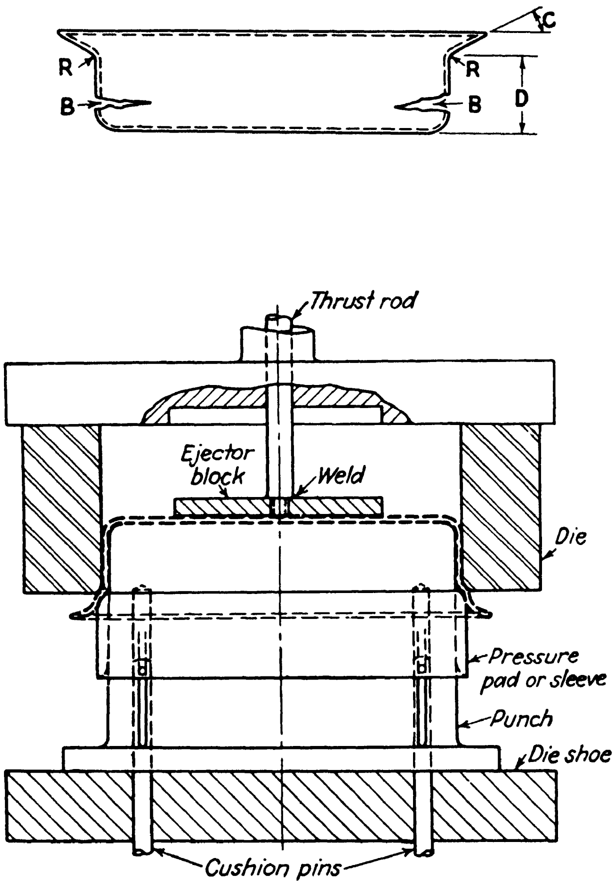


FIG. 170.—An inverted die for the second draw of the shell shown in Fig. 168. At *B* are seen ruptures and other faults that may occur when drawing or redrawing the shell.

This action depresses the rod and block and thus ejects the shell. The pressure plate, or pad, "strips" the shell from the punch when the die ascends by action of the cushion pins. These operations are clearly indicated in the sketches of the two drawing dies.

Correcting Difficulties.—In determining the drawn shapes of the intermediate shell, such as in Fig. 169, it is found that ruptures may appear at the points where the maximum drawing tension occurs, as at *B* in Fig. 170. There are several remedies for this trouble, namely,

increase radius R so that the metal will slip into the die opening more easily, increase angle C for the same purpose, or decrease dimension D, which is the depth of draw.

Sometimes it is found that the circular clearance at places between the punch and die is less than the thickness of the work material, and metal must be removed at these places within the sides of the die. This does not change the drawn size of the shell, because the shape and size of the shell will follow that of the punch. Another cause of ruptured shells is that the blankholder pressure is excessive. Changing one or more of the foregoing conditions will avoid the trouble of torn shells.

Drawing and Redrawing Oblong Shells.—In Figs. 169 and 170, we have the ideal conditions for drawing and redrawing shells without wrinkles. In both cases the metal is drawn down over the punch, as the die descends, and pulls the blank from under the tension between the pressure plate and the die face. The primary cause of wrinkles is unconfined metal, but the best part of this story is that these wrinkles can be controlled by using properly designed dies. In Fig. 170, a previously drawn shell fits over the pressure pad when the pad is up. As the die descends, the metal is forced into plastic flow over the pressure pad, and up into the die by the punch. In this way the metal is subject to constant confinement and perfect control. With these conditions there is no chance for wrinkles to start. In drawing and bending operations, metals should never be stressed beyond their elastic limits. If this is allowed to occur, the work will be permanently weakened at those points.

Trimming Shells.—Square-edged trimming around the mouth of the finished shell, Fig. 168, can be done by leaving a right-angled flange surrounding the opening. The flange is then trimmed in another die, notched, waved, cut straight, or in a variety of desired contours; it is then pushed through the same die by the entrance of the next shell, which straightens up the flange on the first shell. The amount of metal to be trimmed off is added to the height of the finished shell before figuring the blank size. A further description of this method of trimming is given in the next section.

DRAWING AND TRIMMING SHELLS

Trimming the Flange.—It is possible, and highly profitable, to trim-cut light-gage shells around their top edges, by making the desired cuts in a flange that has been left for the purpose around the mouth of the shell. The flange is provided on a first operation shell and is drawn at right angles to the shell walls. After the trimming is

done, the cut flange is then straightened out by pushing the shell—closed end first—through the drawing die. A typical result showing such operations is seen in Fig. 171. Here a cylindrical shell having four trimmed prongs, equally spaced around its edge, is made from the first operation flanged shell shown in Fig. 172.

Straightening the Flange.—There are a large variety of shells that can be successfully flange-trimmed and then pushed through the same

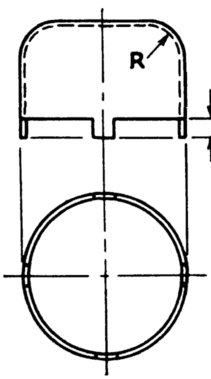


FIG. 171.—A finished trimmed shell with four projecting prongs. This shell is made from the one shown in Fig. 172.

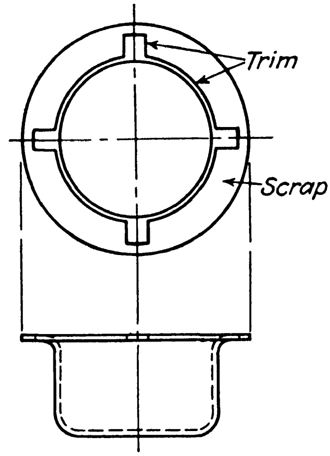


FIG. 172.—First operation flanged shell showing the initial trimming cut in the flange around the mouth.

die by the next oncoming shell, thus straightening up the flange and completing the job. This operation is possible when radius R is greater than height B of the prongs. If B is greater than R, the ends of the prongs will be pinched and distorted between the outside diameter of the oncoming shell and the inside diameter of the die.

Saves One Die Operation.—When possible to employ this kind of an operation, it saves extra handling of the work by eliminating one operation. The shell shown in Fig. 168 can be flange-trimmed and straightened out by using this method. The operations just described can be used for various cross-sectional shapes of shells, as well as for cylindrical shapes.

The advantages in flange trimming and straightening out of light-gage shells are several, especially for the small manufacturer. (1) It is a regular high-production operation. (2) It saves the cost of designing and building expensive trimming dies which usually result in slow operations. (3) It saves purchasing special trimming dies.

Producing the First Operation Shell.—Figure 173 represents a die for producing a first operation flanged shell ready for trimming. The shell is blanked and drawn from strip stock. This die is the inverted type and is similar to others which have been illustrated and described.

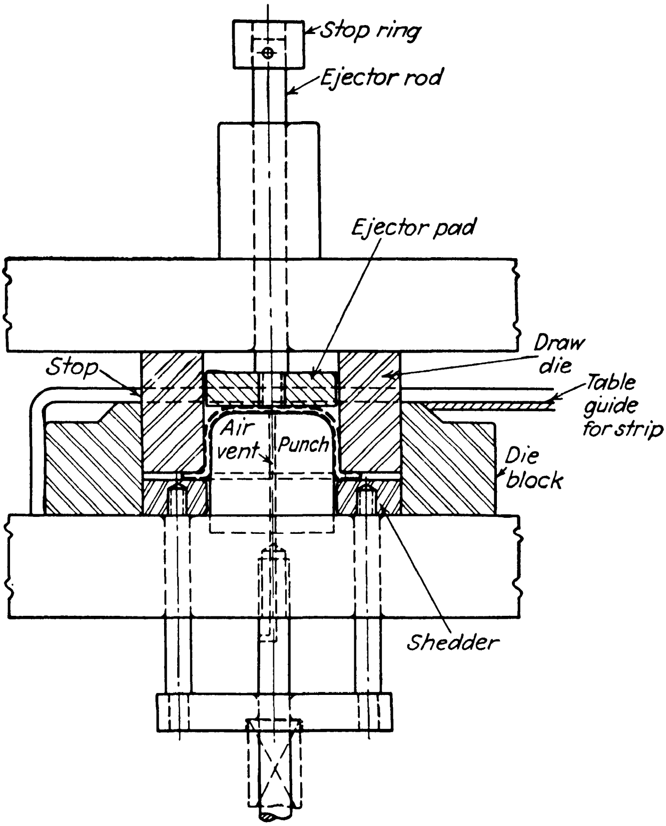


FIG. 173.—Low-cost blanking and drawing die for rapidly producing flanged shells by cutting them consecutively from a strip.

However, this die is of simpler design than a similar one shown under Fig. 176 because the drawing operation is an easier one. The die in Fig. 173 does not trim the shell, neither is it provided with a stripper plate. The stock strip is of such width that blanking severs it; thus stripping becomes unnecessary. It is well to consider this design of die for drawing either flanged or plain shells of various cross-sectional shapes.

Trimming and Straightening Simultaneously.—Figure 174 presents the details of a trimming die used for producing the trimmed shell in Fig. 171, by using the flanged shell produced in the die, Fig. 173. The principal features in this die include a safety feeding chute *C*, which

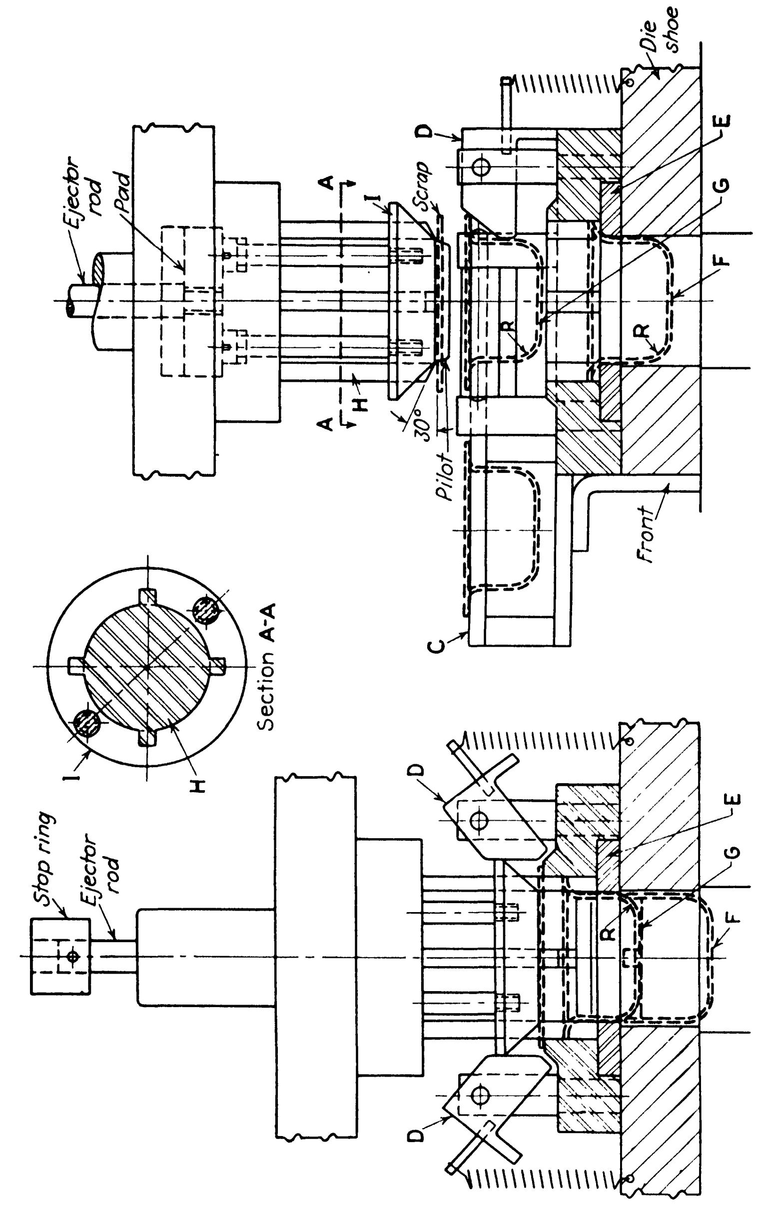


FIG. 174.—Die for trimming a flanged shell and then straightening its four trimmed prongs all in one operation.

takes one flanged shell at a time; three bell-crank levers D, provided with angular noses for supporting the shells before the punch descends, and the straightening ring E.

This die is set up on a tilted press. It trims the flange around a shell with a press-crank stroke of sufficient length, when the punch descends, to push the previously trimmed shell F through the straightening ring; this is done by contact with the oncoming shell G, as indicated in the front elevation view. Shell F then falls through the die shoe and beneath the press.

It will be observed that trimming punch H has a centering pilot that enters the mouth of the shell; that its four trimming points have 30-deg. angular faces that partially "throw up" the prongs when cutting; that stripper plate I has an angular edge which, in descent, depresses the three bell-crank levers; and that the scrap is "stripped" from the punch, when the ram ascends, by the action of an ejector rod connected with a pad. The press being tilted, the scrap slides off or is blown away by compressed air.

COMBINATION BLANK AND DRAW DIES

Types of Work Done in Combination Dies.—Of the many different types of press tools possible to make, the combination blank and draw principle is probably the most useful, reliable, and interesting. When such dies are designed for drawing cylindrical shells, the working members of the tool are round, and can be rough-turned and sized on a lathe, then hardened, ground, and lapped, if necessary, to specified precision diameters.

But these dies are not always designed for cylindrical work. The longitudinal cross section of the drawn shell may be square or rectangular, with rounded corners; it may be of hexagonal, octagonal, or irregular contour. Perhaps the shell is drawn with a flange surrounding its opening, or without a flange but with its wavy edges trimmed off evenly around the mouth of the shell. The type of shell just mentioned is the kind now under discussion. It is to be produced in a combination blank, draw, and "pinch" trimming die.

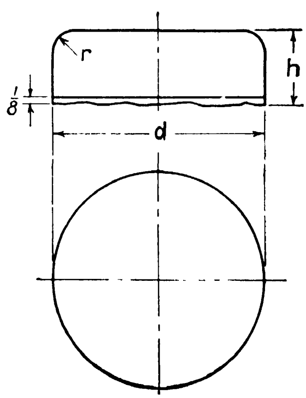
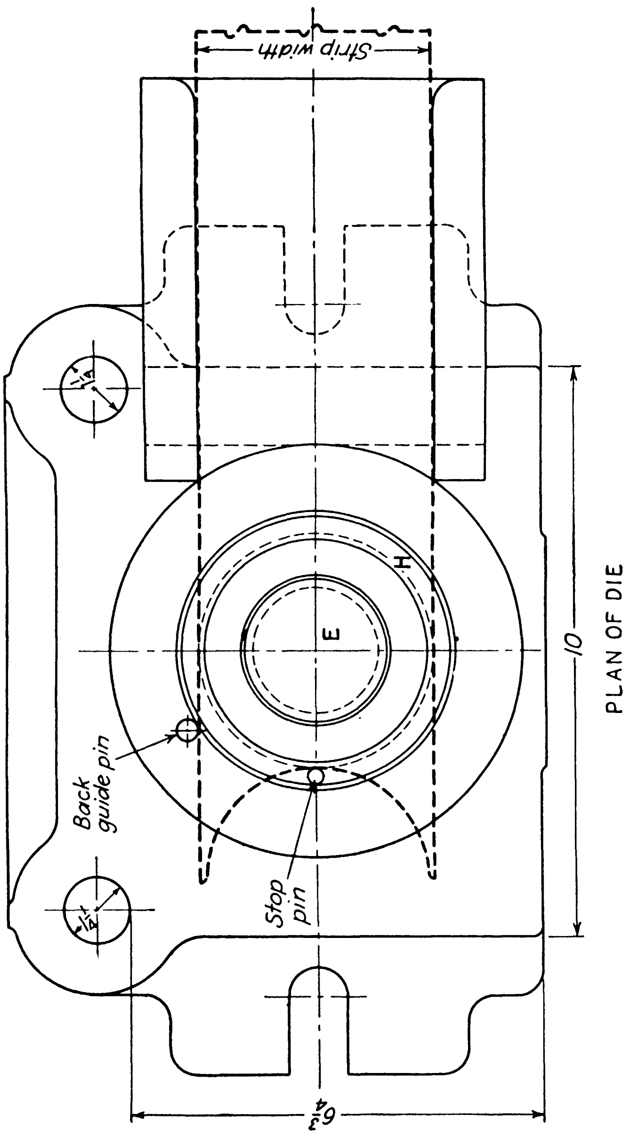


FIG. 175.—The center lines within the walls of a cylindrical shell that has round corners. This shell is to be blanked and drawn and is to have its edge trimmed off, all in a single operation.

Description of the Work.—The outline in Fig. 175 represents the center line within the walls of a shell that is to be produced in the

manner just described. It is to be drawn at a single station in one operation. The material used is 0.0625-in.-gage, S.A.E. 1010 strip steel. This material is known in the shop as "dead-soft" deep-drawing



steel. The height h of this shell includes $\frac{1}{8}$ in. of material for trimming. The first procedure is to determine D, which is the blank diameter. $D = \sqrt{d^2 + [4d(h - 0.43r)]}$. The width of strip is found

by adding twice the material thickness to D. The blanking center distance is D plus one thickness of the strip.

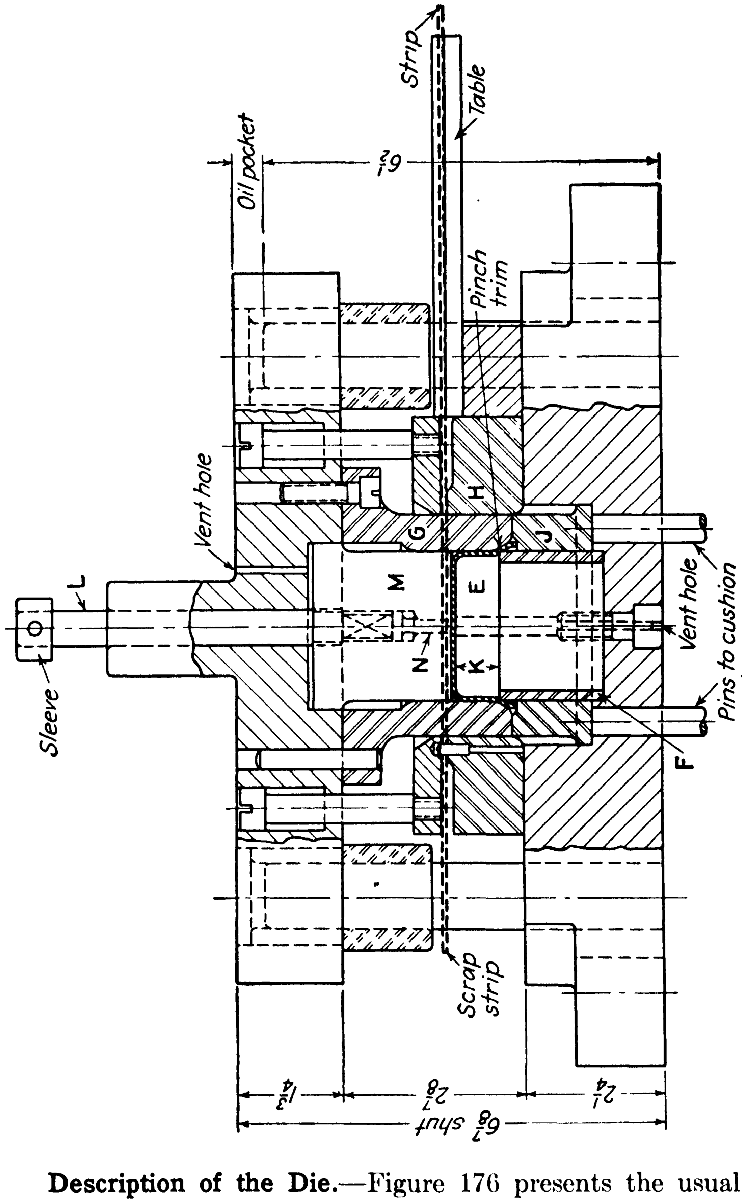


Fig. 176.—Plan of die and a vertical section through the front elevation of a combination blanking, drawing, and trimming punch and die.

Description of the Die.—Figure 176 presents the usual drafting technique for showing the design of a combination blank, draw, and "pinch" trimming die for producing the trimmed shell in Fig. 175, one piece per press stroke. Drawing punch E is centered in the die

shoe. It is a shouldered punch and is surrounded by cutting ring *F*, located under its shoulder.

The outside diameters of the ring and shell, and the inside diameter of blanking punch *G*, are all equal. When the strip is fed against the stop pin and the ram descends, punch *G* cuts the blank into die *H*. The blank is then carried down flat about $\frac{1}{8}$ in. into contact with drawing punch *E*. The ram continues to descend and causes the blank to be drawn down over the nose of the drawing punch while its rim or flange is being pulled taut from between the faces of *G* and *J*.

Shedder *J* functions as a blankholder because of the vertical pressure pins upon which it rests; the pins lead down to a cushion pad situated beneath the bolster. Drawing and forming of the shell continues, as the ram descends, until the portion to be trimmed off the shell reaches the edge on the cutting ring.

Trimming and Stamping the Shell.—The inside diameter of blanking punch *G* and the outside of cutting ring *F* being equal, the surplus of metal, which was added for trimming, is pinched off at the instant that punch *G* closes the space between itself and the cutting edge on the ring. Dimension *K*, of course, determines the inside depth of the drawn shell. Lettering, designs, or trade-marks can easily be stamped in the bottoms of shells by inserting the stamps or characters either in the faces of the drawing punch or in shedder *M*.

Delivery of Finished Shell.—When the ram ascends, the shell is carried up within punch *G*, because it is released by an air vent hole in punch *E*. The work is ejected by the thrust of knockout rod *L*, which is attached to shedder *M*. This rod is operated on the upstroke by contacting an adjustable crossbar through the head of the press. The press being tilted, the shell slides off the die at the rear, and the trimmed scrap is blown off by a jet of compressed air. The sleeve pinned on the top of the knockout rod prevents damage to the ejecting mechanism if the die setter should inadvertently operate the press when the crossbar is set too low.

Using "Push-off" Pins.—The completed shell is pushed away from the face of *M* by the action of the spring push-off pin *N*. Push-off pins are usually necessary to remove work from dies in which the piece fails to fall by gravity alone. This may occur because of the adhesiveness and vacuum, between the punch and work, caused by the lubricant used for drawing.

Grinding the Die.—The trimming ring can easily be removed for grinding its face. A similar amount is then ground from the bottom of the drawing punch and from the top surface of die *H*, thus maintaining their relative positions in the die. In making drawing punch *E*

and shedder *M*, an arbor is inserted through their center holes and used for grinding them concentrically.

COMPOUND DIE FOR BLANKING, DRAWING, AND PIERCING

Tool Engineering in the War.—Tool engineering takes a prominent part in the war-equipment program. Therefore it is a good plan to

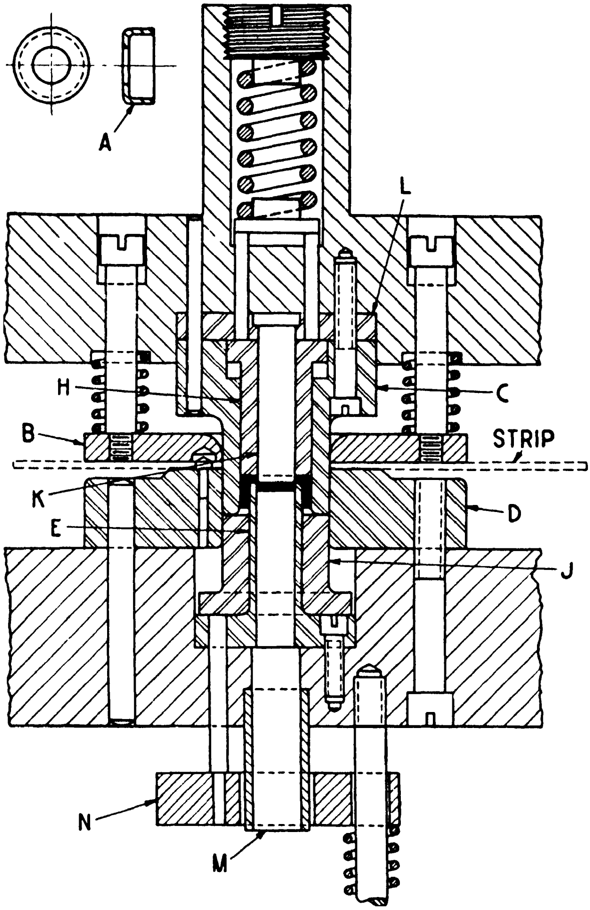


Fig. 177.—Design of a compound blanking, drawing, and piercing punch and die for producing large quantities of the shell shown at *A*.

have conveniently at hand some of the standard designs for tools and dies which are most likely to confront the designer. A detailed reference often saves unnecessary study and time lost in attempting to design new tools that have been made many times before.

Designing Combination Blanking and Drawing Dies.—To design and arrange all the stationary pieces and working parts in a compound

blanking, drawing, and piercing combination die for producing the shell *A*, in Fig. 177, may be quite a difficult task. The pierced center hole is comparatively large. It is very necessary that the drawing and forming of the shell be finished before starting to pierce; otherwise the hole would be distorted.

Order of the Die Operations.—In the operation of this die, when the ram descends, spring stripper plate *B* contacts the strip and holds it down firmly by means of four compression springs. The ram, continuing to descend, causes the blanking punch *C* to cut the blank into die block *D* and to carry the blank down into the die, as shown in Fig. 177.

Next, the blank in descent contacts the nose of drawing punch *E*, against which it is held by the pressure of shedder *H*. Shedder *H* is actuated by a large compression spring in the punch-holder stem. Continuing downward, the blanking punch draws and forms the blank down over the positive punch *E*.

The length of the piercing punch *K* is such that when the shedder *H* registers against stop plate *L*, the punch contacts the finished shell and pierces the hole just before spring shedder *J* registers on the flange of forming punch *E* in the die shoe.

When the ram ascends, the work is stripped from drawing punch *E* by the ascent of spring shedder *J* and is ejected from the blanking punch by the action of shedder *H*. Stripper plate *B* removes the scrap strip from the blanking punch. The press being inclined, the finished shells slide off into a tote box placed behind the press. The short length of tube *M*, inserted under the die shoe, carries the pierced slugs safely through the movements of spring plate *N*.

An Error Good Designers Sometimes Repeat.—One of the common errors that occur when attempting to cut off and draw shells progressively is shown in Fig. 178. It is surprising that good designers will fall into this error more than once. The reason may be the desire to build a cheap tool rather than one that will work. This error becomes even more misleading when it is recalled that the well-known progressive operation as shown at *A* is often successfully done.

The truth about this kind of an operation is that its success depends upon the depth, shape, and material of the proposed shell. If the depth is less than the shell diameter, and the cross-sectional shape is favorably elongated instead of round, and if the punch and die radii are the right sizes, then, by using very ductile and fairly thick materials, the operation is practical. Under any other conditions, most of the shells will show ruptured corners, as seen at *B*.

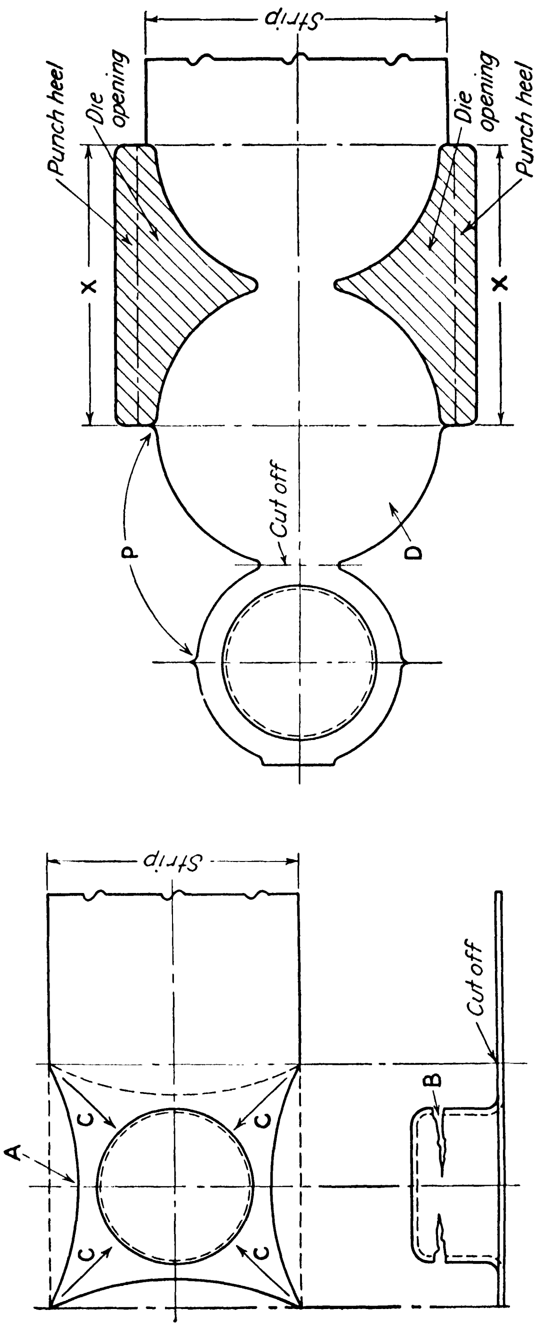


Fig. 178.—Showing depth of shell, distortion of the strip, and difficulties to overcome when drawing and cutting off shells progressively.

This trouble is caused by the restriction of plastic flow in those parts of the strip as indicated by directions *C*. At these places, it is not possible for the punch to draw in enough metal to form a deep shell that will be free of fractures. Of course, the logical remedy is to introduce another station having trimming punches with backing-up heels and to trim out the restricted area of the blank, as shown at *D*. To add these trimming punches is an expensive change. The original die set must be set aside and a new one ordered, but the change could have been easily incorporated in the original die. There must be an idle station between the added station and that of the draw, as seen at *D*.

A Compound Blanking and Drawing Die.—Briefly, drawing dies of these designs are inverted types. The shell is drawn up into a die mounted on the punch holder. A spring pad or blankholder surrounds the drawing punch, which, in turn, is mounted on the die shoe. A knockout pad, with an attached vertical rod, is provided in the drawing die opening for ejecting the work when the ram ascends. The blank is severed from the strip by a cutting-off blade, which is attached across the right end of the drawing die. The lower cutting member is the left end of the trimming die block. The sharp points *P*, which remain on the work, are subsequently trimmed off along with the flange around the shell. For work where these points would be objectionable, lengths *X* of the trimming punch and die are increased enough to remove the points.

REDUCING COSTS OF LARGE DRAWING AND FORMING DIES

The Facility of Using Hardwoods or Composition Materials in the Construction of Certain Types of Dies

Building Drawing Dies Mostly of Wood.—If hardwoods, or some of the excellent substitutes now available, were used wherever possible in large dies now made of steel, thousands of tons of this metal could then be released for other useful purposes.

While this change would be impractical in precision dies—they are too small for inclusion in this list anyway—there are reasons enough to believe that it would be an economical change in large drawing and forming dies.

Some manufacturers are already following this idea in the initial design and construction of new dies for tank and airplane parts, such as the deep drawing of aircraft landing-gear wheel pockets.

New Die Stock Material.—A comparatively new die stock material is now available as a substitute for hardwoods.* It is a semi-

* Masonite.

plastic composition without cross or end grain. It does not shrink or present other difficulties in working. It can be cut with hand tools or in power machines, like wood. Yet it has far more compressive strength than hardwoods, and its absorption of moisture is less than 1 per cent. It can also be laminated to any thickness by using cold-setting glues between the sheets. Sheets are made up to 4 by 12 ft. and in many thicknesses from 1/4 to 2 in.

It is said that this material will not crack, twist, check, or warp. It eliminates the necessity of frequent reworking of dies, because the dies will "stand up" almost as long as though made entirely of steel. It has also been largely used in connection with soft rubber pads for shearing, forming, and bending operations in hydraulic presses in which the patented Guerin process is used. Aircraft builders and other manufacturers favor using this material because it combines light weight with high compressive strength. Moreover, it can be fabricated and assembled in dies ten times more rapidly than steel parts.

Large Drawing Dies with Hardwood Spacer Blocks.—Figure 179 is the sketch for a large cylindrical shell drawn in the die which has the simplified construction indicated in Fig. 180. This tool is constructed of hard maple blocks faced with steel. All the steel parts needed in the construction of this tool are simply a punch face, a comparatively thin drawing die block, and a pressure plate or blankholder. Even the blankholder is unnecessary if the shell material is thick enough to resist wrinkling while being drawn.

The partially drawn work in this die is shown at *A*. The shell appears to be about half finished. When the punch completes its downstroke and begins to ascend, the finished shell at *B* is "stripped off" by contact around the under die edge *C*, and the work then falls out beneath the die and through an opening in the bed of the press. Such types of press tools are sometimes called "drop-through dies."

Coiled compression springs are used here to put holding tension on the pressure plate, but the springs can be dispensed with if the die is designed for use in a double-action press. In a double-action press, the pressure plate is attached on the blankholder gate, which is the outer ram. In either case, the pressure plate holds down the blank taut over the die but allows it to slip from under it when the punch descends through the pressure plate and draws the shell down into the die.

It is very important that the tension on the pressure plate be adjusted correctly. If it is adjusted too loosely, wrinkles will form in the blank. On the other hand, if the adjustment is too tight, the punch may rupture the corners or tear open the sides of the shell

before it has been completely drawn. Therefore, the tension must be adjusted between these two extremes, and that is a part of the die-setter's job.

It is easily apparent here that many large drawn parts such as automobile fenders, large culinary ware, and aircraft parts can be

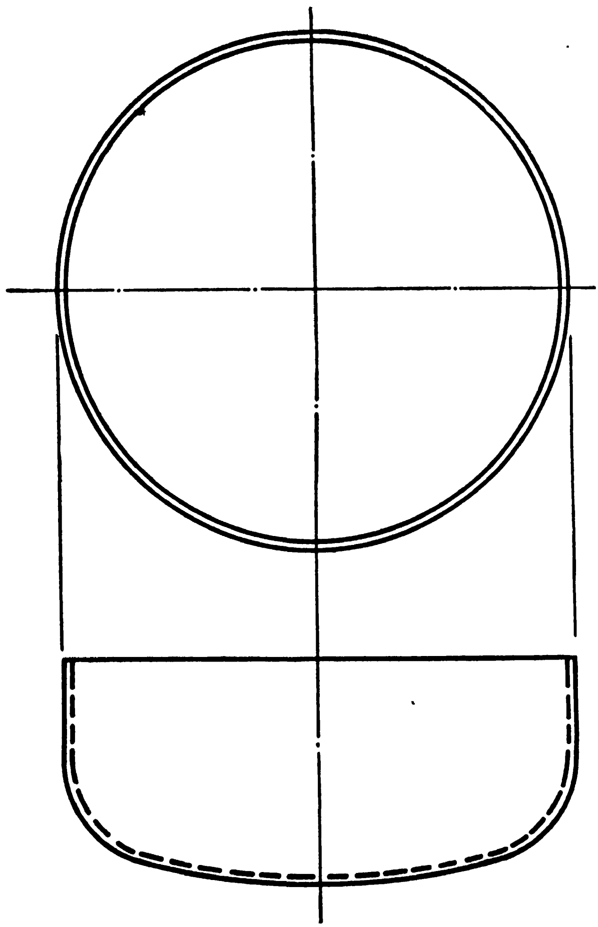


FIG. 179.—This large cylindrical shell has two different designs of dies for drawing it, each of which is illustrated and described.

produced in dies of these types. It can also be seen that large bends and forming operations can be done in straight flat work, and that the pressure plate would then be unnecessary. But in some cases of bending and forming thin stock, the pressure plate may be needed in order to hold down the free ends of the work while the forming operation proceeds.

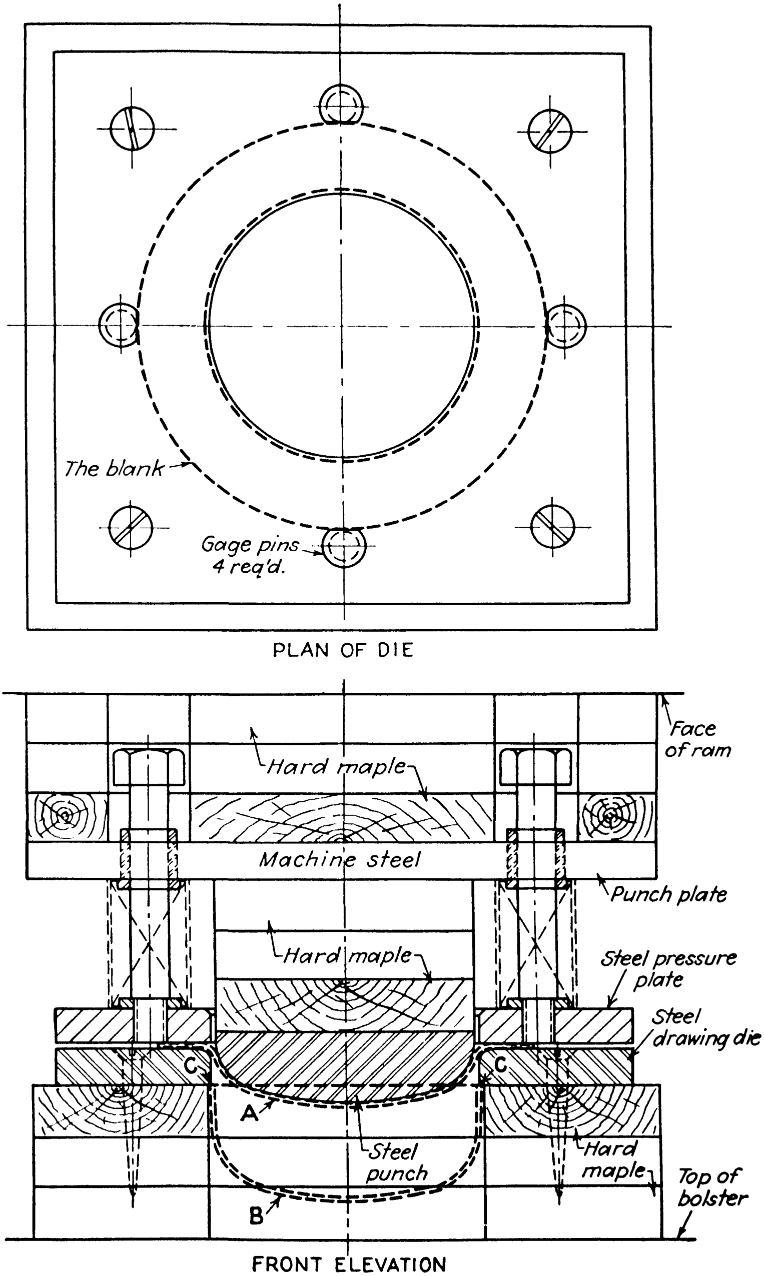
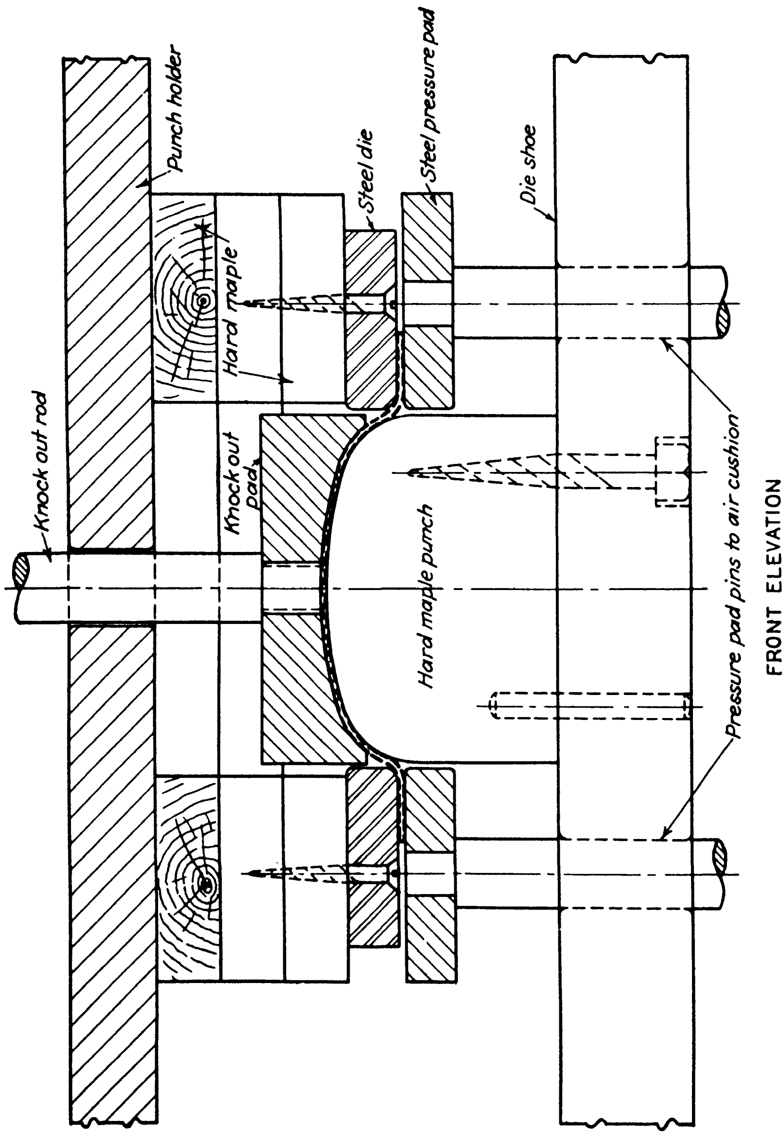


FIG. 180.—Conventional design of a low-priced drawing die, largely of hardwood construction, for producing the shell sketched in Fig. 179.

Large Inverted Drawing Die with Hardwood Punch.—In all drawing operations, the die takes most of the wear and abuse, while the punch simply governs the inside size and shape of the shell. This



being so, we have in Fig. 181 two views of an inverted drawing die in which the punch is of hard maple and the drawing die a plate of steel.

This press tool is designed in reverse order as compared with the conventional die; that is, the die is located symmetrically over the punch, the former being attached on the punch holder and the latter

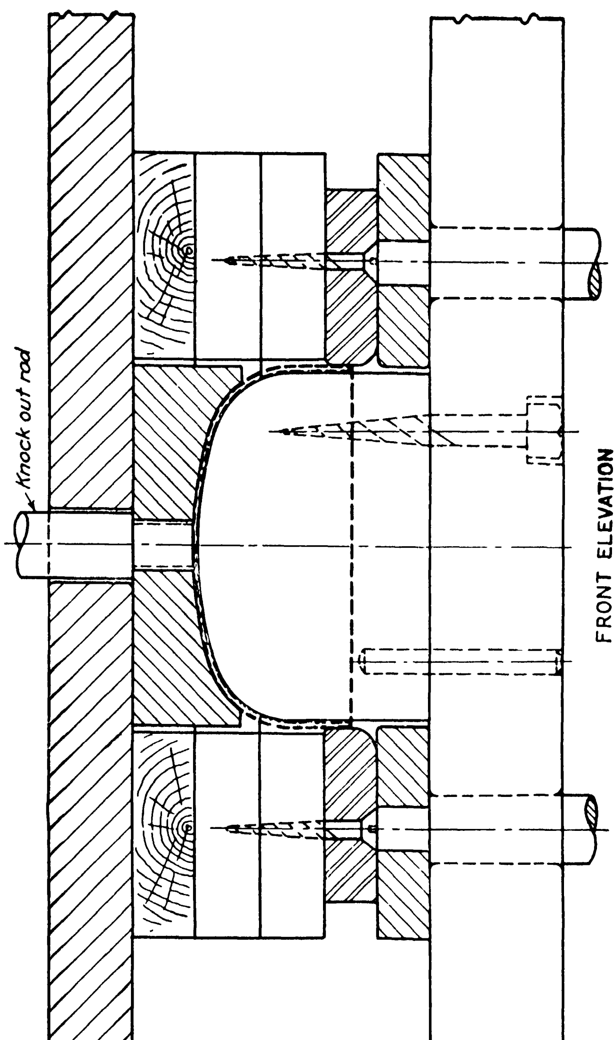


FIG. 181.—Two "slow-motion" views of a low-priced inverted drawing die, made almost entirely of hardwood, for drawing the shell shown in Fig 179.

on the die shoe. In this case, the pressure pad surrounds the punch. It rests upon vertical pins that extend down through the die shoe and are actuated by an air cushion attached under the press.

In the upper view, the ram has just begun to descend with the die attached. The drawing of the shell is not quite half completed. In the lower view, the die is closed, and the shell has been completely finished. When the ram ascends, the shell is carried up within the die and is ejected by a "knockout" pad attached on a vertical rod that is pushed down automatically near the maximum upstroke. All these dies are simple, easy to construct, of cheap materials and light weight. The construction costs are therefore low in comparison with those of all-steel tools.

Fabrication of Certain Aircraft Parts in Germany.—For streamlined Duralumin parts in which the sheet curvatures are generous sizes of "sweeps" such as used in fairings and fuselages, the parts are hydraulically stretched to size and shape in a Henschel stretching press. These machines remind one of a large pair of book ends. They are composed simply of two L-type cast-iron "heads," each about 30 in. high. The vertical planes of the L sides face each other, and the short leg of the angle is bolted on an adjustable slide built in the shop floor. With this adjustment and a locking device the heads can be "set" at any reasonable distance apart, from face to face, as seen in Fig. 182. This photograph was taken in a German aircraft plant before invasion of the Low Countries.

Between the heads, a vertically operated hardwood punch is arranged. It is operated by a piston from a hydraulic cylinder situated beneath the floor. The punch face, being of wood, is easily shaped to the desired planes, outlines, or sweeps to which the sheet is to be stretched. The work sheet is bolted between clamp plates at the tops of the "book ends" and extends across and over the face of the punch. The sheet is held taut by slowly separating the L frames and then locking them. Next, the punch is caused to ascend, contacts the sheet, and, continuing to ascend, stretches the sheet to conform with the surfaces on the punch. More than one-third of Germany's Hs-126 types of observation planes are composed of stretched parts produced as just described or of drawn metal and die stampings.

Drawing and Indenting Simultaneously.—The operation illustrated and described consists of drawing the box cover shown in Fig. 183, and at the same time forming an indent *A*, at one end of the cover's edge. The indent is for the purpose of removing the cover from the box on which it is used. The work material is No. 28 (0.0156-in.) U. S. G. auto-body steel. The die itself is mounted in an ordinary commercial type of die set having two guideposts in the rear, as illustrated in Fig. 184. The die is used in a press which is tilted back.

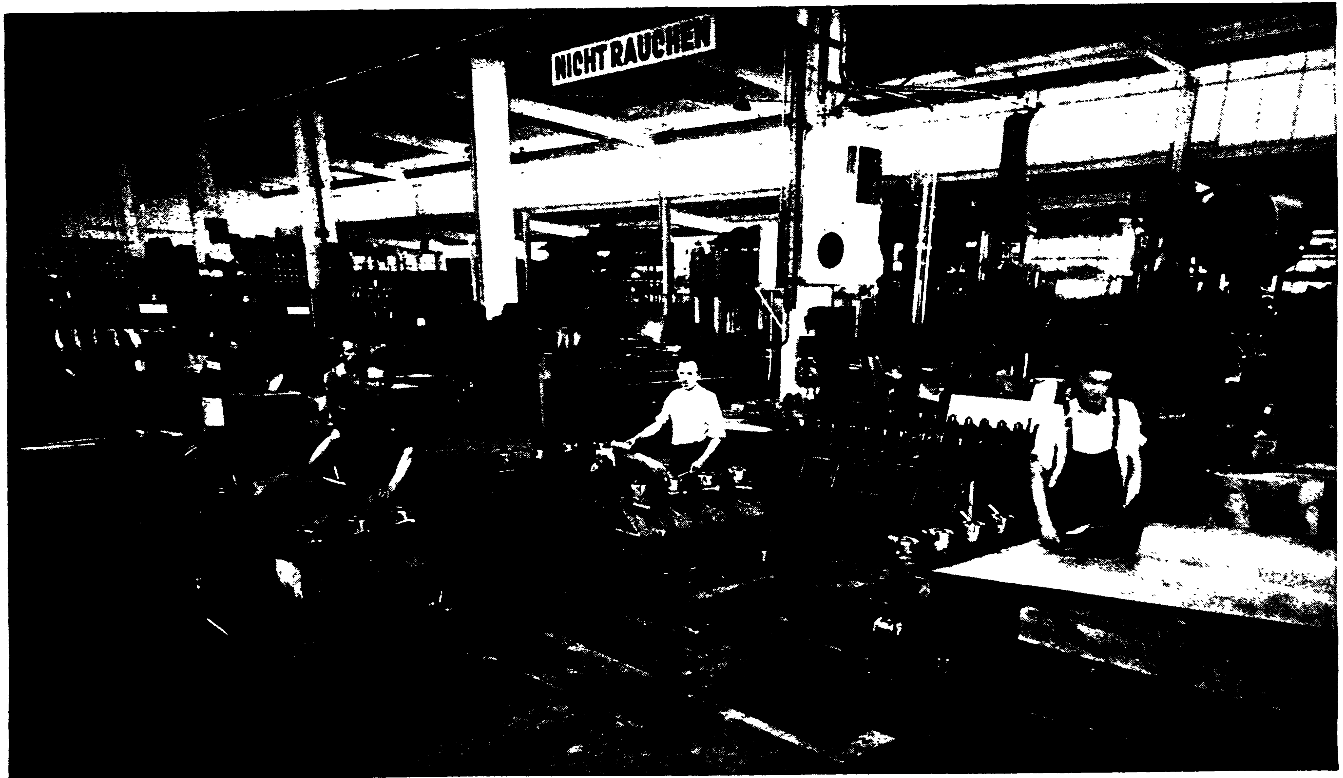


FIG. 182.—In Germany, aircraft fairings and sheet metal "skins" are drawn to shape in stretching presses. Clamps on both sides of press hold the sheet in contact with a wooden form, or punch, the latter being slowly elevated, between the clamps, on a hydraulic plunger actuated by a cylinder beneath the floor. (*Courtesy of American Machinist.*)

This tool drawing is an example of the drafting technique employed in making views of ordinary press tools. The faces of the punch holder and punch are shown at the right of the plan. This view is the result of having lifted the punch holder straight up from its normal position over the die, and then turned it clockwise 180 deg., "face up."

The blank for this cover is previously cut in a two-step piercing and blanking die. It is then fed into the die shown in Fig. 184, through a chute as indicated in the plan view. When the ram descends, and the face of drawing punch B contacts the blank, two pilot pins in the punch also register within corresponding holes in the blank. This action

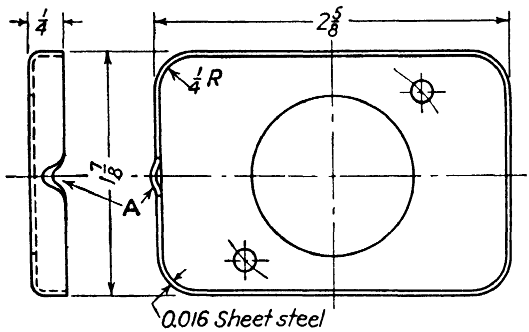


FIG. 183.—Sheet metal cover with an indent formed at A. The indent is produced on one edge of the work in the same die that draws the cover.

ensures that the sides of the cover will be drawn up in a symmetrical position around the holes when the punch, in descent, carries the blank down into the drawing die block C.

This is a compound drawing die, that is, it is provided with a shedder pad D, situated under the work. The shedder is depressed against spring plate E and spring F, when punch B descends with the work. On the upstroke, the shedder follows up and ejects the finished cover from the die.

Forming the Indent.—When the ram descends, a positively adjusted vertical stud G contacts under lever H and depresses the indenting punch J. Punch J works in an angular slot as shown. In descent, it moves both forward and down simultaneously, making contact with the vertical edge on the drawn work and forming the dent. At the maximum downstroke, shedder D "banks" on the die shoe. The punch then "spanks" the work flat.

When the ram ascends, the shedder follows, and the indenting punch withdraws under pressure of the coiled compression spring K. The finished cover is "stripped" from the punch by action of the knock-off rod, which is depressed by contacting the knockout bar

through the head of the press. This occurs when the ram has almost reached its highest ascent. The press and die being inclined, the work falls behind the machine.

This type of die operation, though quite simple, suggests the possibility that similar operations might be performed in drawing dies by attaching the device shown by members *G*, *H*, *J*, and *K*. Indents could be made at several places around the rim of a shell, edges could be curled, or slots cut and folded in the edges of the work, at the same time that drawing is done.

Die Elevated Vertically Does Difficult Drawing.—Experiments in handling aircraft parts have developed a punch press incorporating the advantages of a hydraulic press, a drop hammer, and a stretching press, adapting these features to aircraft production.

On each upstroke of the punch the die is elevated a predetermined distance by means of a hydraulically controlled bed. The bed is positively locked during the downstroke. Each time the punch descends it is thus forced to enter deeper into the die and work in uniform depths (see Plate XXXII, page 441).

When using a light-gage metal, as little as $\frac{1}{16}$ in. can be drawn at each stroke, causing the metal to "flow" instead of stretch. These short consecutive draws tend to shrink rather than tear the metal. Heavier gages and metals with higher tensile strengths can be drawn deeper than $\frac{1}{16}$ in. at each step; but at no time is it necessary to draw so deep as to create a "thinned" condition of the work so common to drop-hammer and conventional drawing operations (see Plate XXXIII, page 442).

Double-action Presses.—These presses have two rams, one within the other, and they are of two general types: one in which the outer ram, or the blankholder ram, is cam actuated, and another in which the outer ram is operated by toggle links. Double-action presses are made as small as bench sizes and up to other sizes large enough to draw sections of automobile bodies. The press frame construction is the straight-side type.

The principal applications of these presses are blanking and drawing, but they may also be used for hot sizing and forging and for several other purposes where two related operations are involved. Shells have been redrawn in double-action presses. A sleeve attached on the outer ram is brought down and used as a "hold-down" within the shell, while a punch attached on the inner ram descends through the sleeve and redraws the shell by pushing it through the die. In this operation the shell is properly centralized over the die before drawing begins.

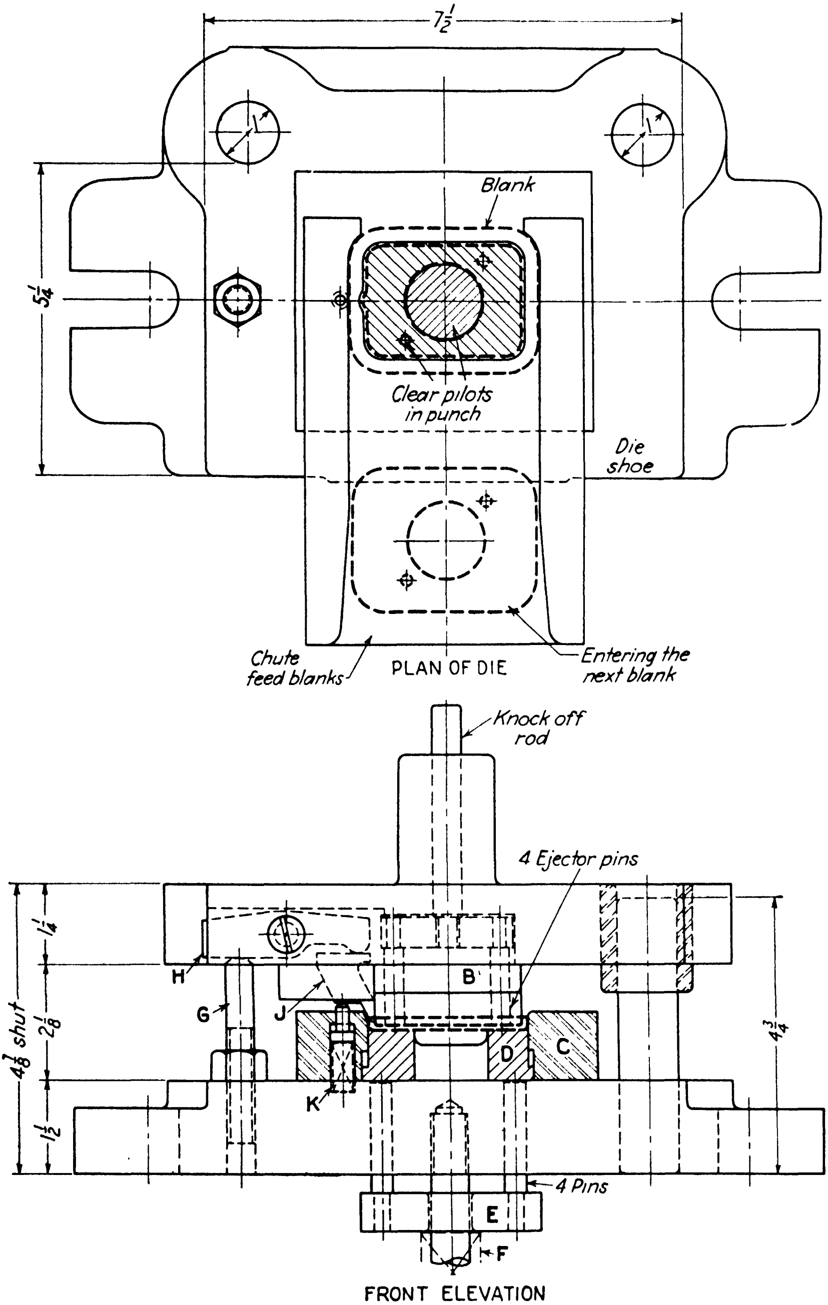
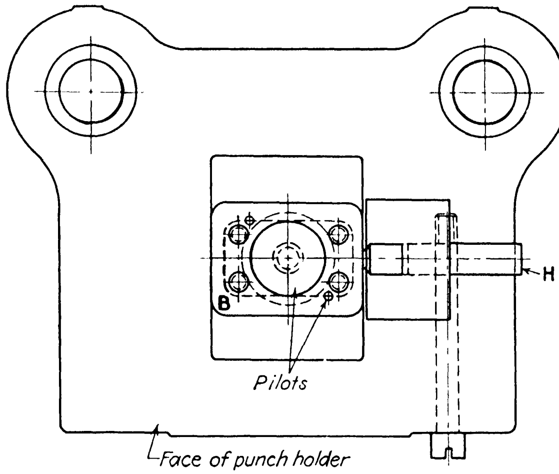
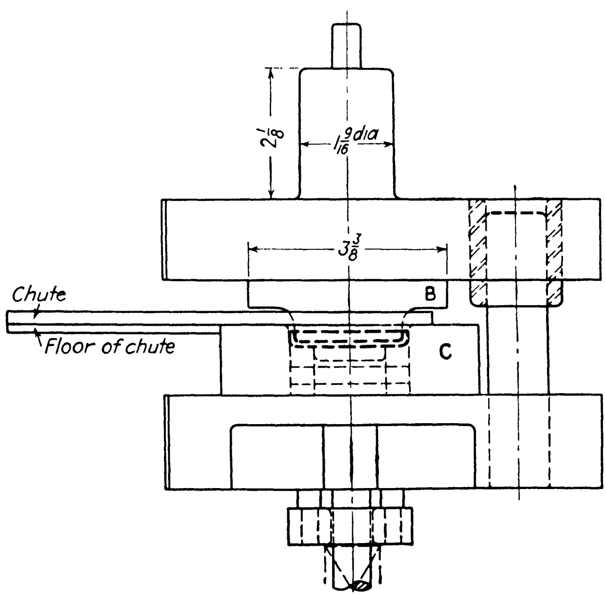


FIG. 184.—Die for drawing and indenting one edge of the cover as shown at *A* in Fig. 183. The blank is pierced and cut in a previous operation and is fed into this die through a chute attached in front.

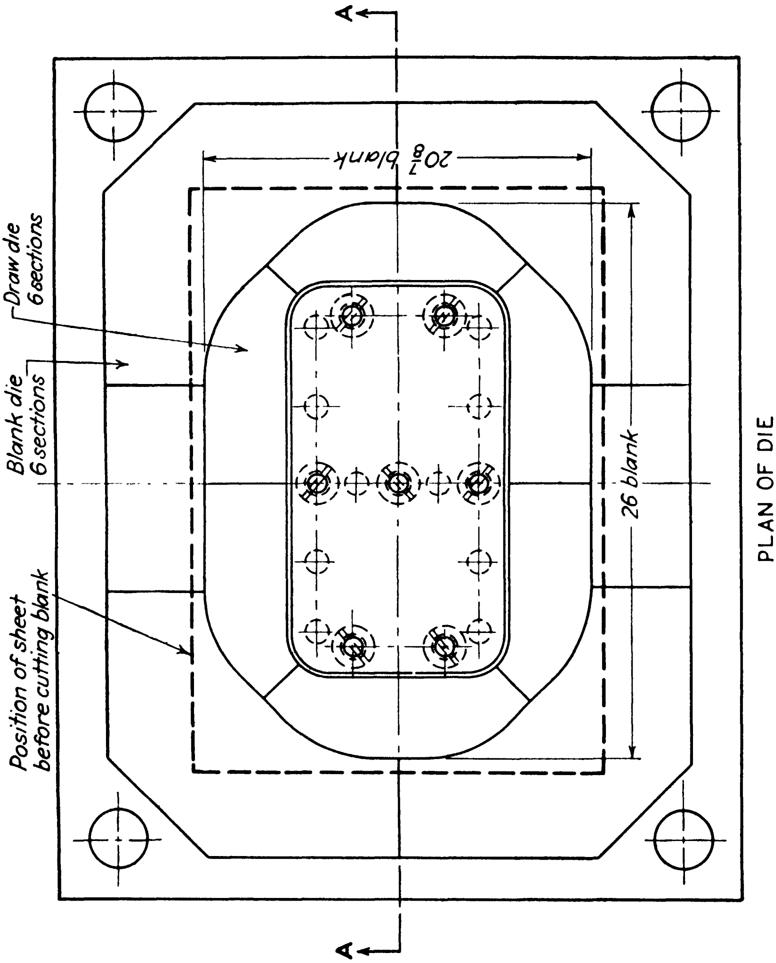




RIGHT END ELEVATION

FIG. 184.—(*Continued*).

Die for a Double-action Press.—Figure 185 shows the drafting technique and tool design for most types of double-action dies used for combination blanking and drawing of shells. Notice in section



A-A that the usual section lining is omitted. This saves much drafting time and is an especially economical stunt in drafting wartime tools. Anyone who is accustomed to reading mechanical drawings can readily understand the tool parts in this sectioning.

The blank and the first and second draws of the work, a steel container, are shown in Figs. 186 and 187. This die is shown in a closed position. When the rams are up, the sheet is fed forward against a

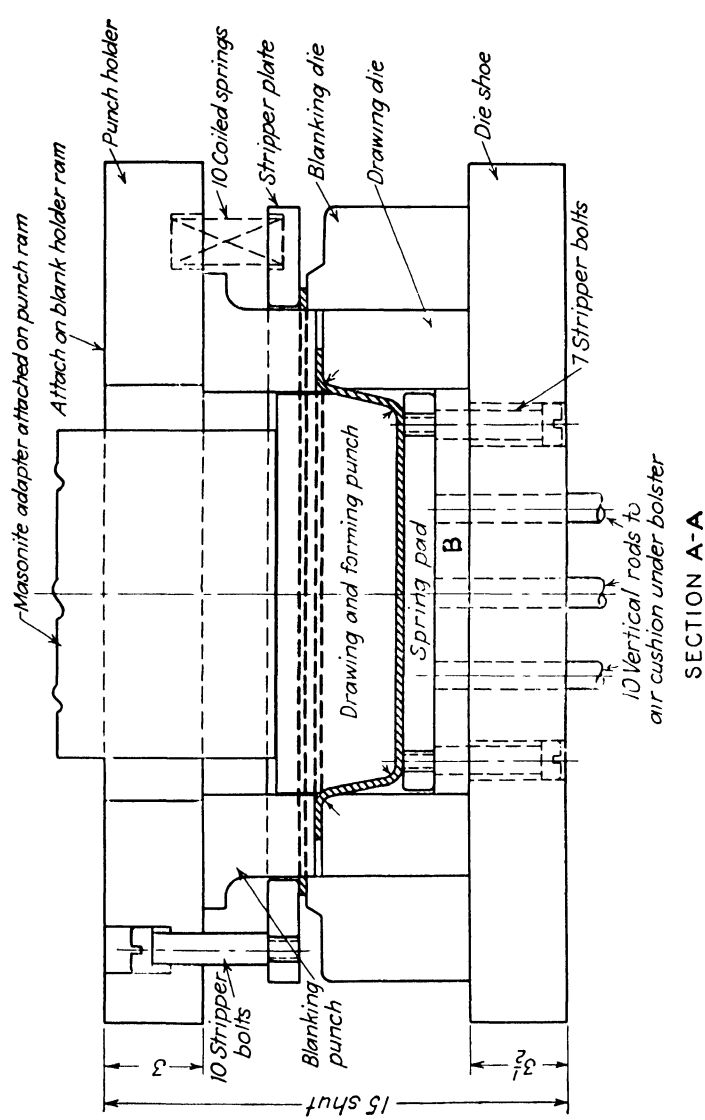


FIG. 185.—First operation double-action blank and draw die for producing the steel container shown in Figs. 186 and 187.

stop, thus exposing another blanking area. The clutch is then "tripped," and the outer ram and stripper plate descend ahead of the blanking punch. The plate holds the sheet down while blanking.

The blanking punch, also attached on the outer ram, then cuts and carries the blank down against the face of the drawing die and holds it taut, while the drawing punch on the inner ram descends and draws the

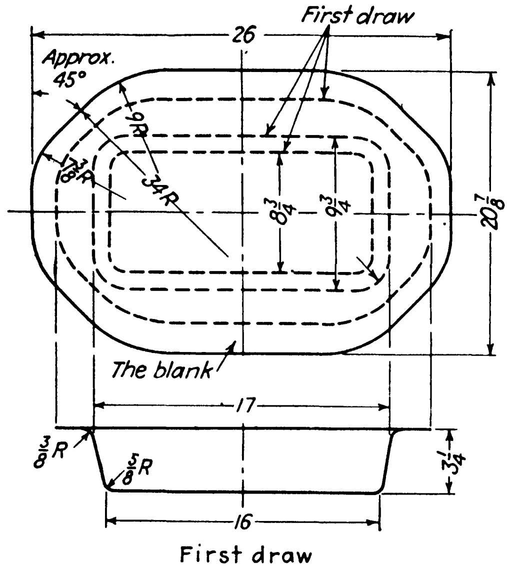


FIG. 186.—First draw of a container produced in the double-action die shown in Fig. 185. The blank is of deep-drawing steel.

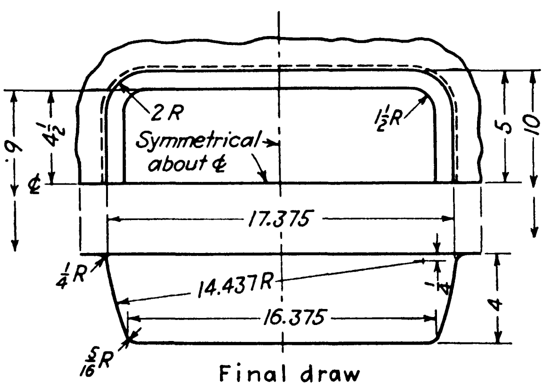


FIG. 187.—Final drawing and stretching of the first drawn container completing the work ready for trimming.

shell down into the die against a spring pad. At the maximum downstroke of the inner ram, the spring pad in the die "banks" the work against positive plate *B*, which gives the shell a definite "set" and shape.

When the rams ascend, the spring pad causes the work to follow up with the drawing punch, the stripper plate pushes off the scrap around the blanking punch, and the completed shell falls away from the drawing punch. If the shell adheres on the punch because of oil used for lubricating the draw, or "vacuum lock" and other causes, "push-off pins" can be arranged through the face of the drawing punch for ejecting the work, or a knockout pad is incorporated within the punch.

Stretching Shells.—The sides of the container are given a slight taper in the die shown. This feature tends to avoid scratches on the work and promotes easy ejection. It is also seen by the dimensions given in Figs. 186 and 187 that the final draw is stretched and drawn to shape from the first drawn container. The second press tool used is similar to the first, and its operation is practically the same. The size of opening in the first shell permits the drawing punch of the second die to enter it by a clearance of 1/8 in. The punch then continues to descend and thus stretches and draws the first container to the inside dimensions and depth shown in the final draw.

Substituting Cheap Materials to Save Steel.—In some very large dies, cast iron or semisteel punches and dies are used to save tool steel. This can be done if a few minor scratches on the work are permissible. There are several grades of cast irons on the market that can be finished smoother and stand up better than ordinary cast iron in drawing dies. One of these metals, known as "Meehanite," has wear-resisting properties that give it a superior place in making dies for forming, pressing, drawing, and stamping of sheet metals. Masonite and Kirksite are commercial materials largely used for dies in aircraft production. The former is an easily worked plastic composition, the latter a hard tough metal alloy.

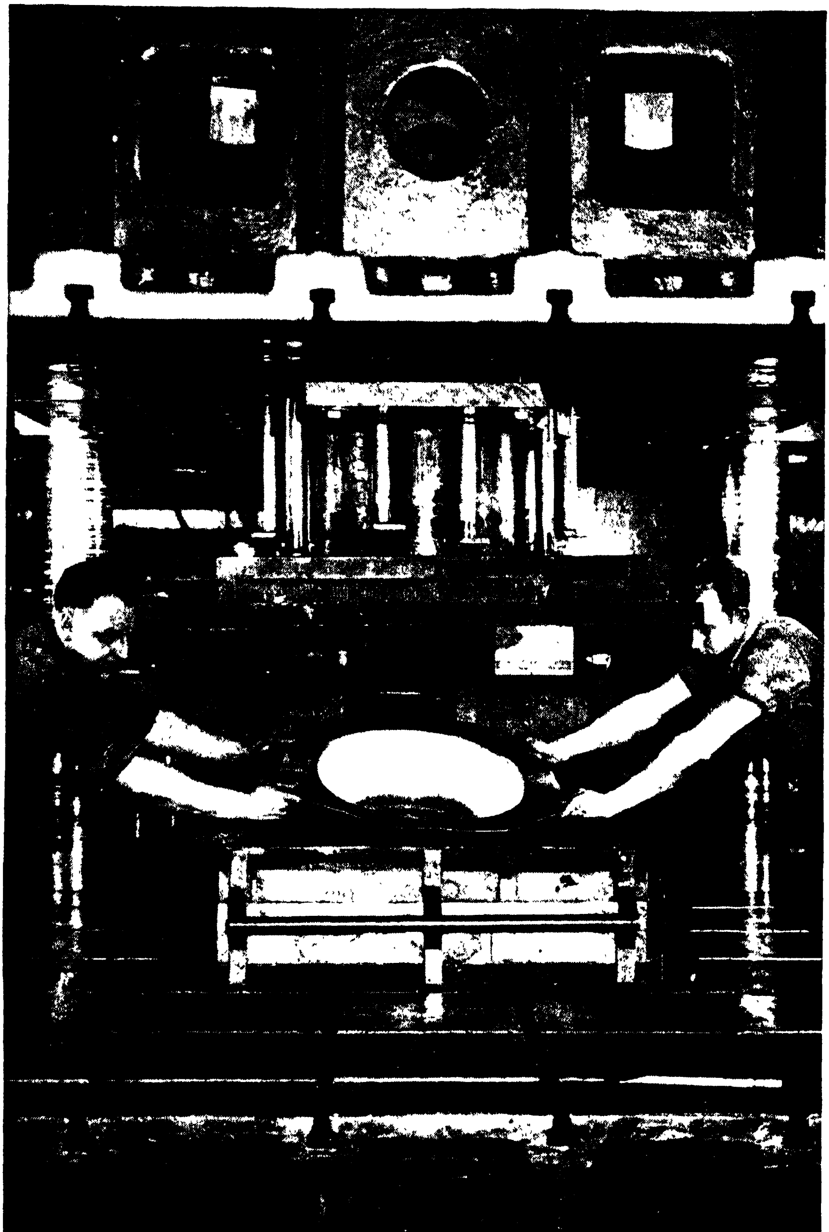


PLATE III.—A drawing die of Masonite construction. Removing a large drawn shell from a conventional drawing die used in a hydraulic press at the Grumman Aircraft Engineering Corporation's plant, Bethpage, N. Y. The shell is designed for a landing-gear wheel pocket, and its flange is to be subsequently trimmed for attaching the shell in an aircraft assembly.

CHAPTER X

CALCULATING SHELL BLANK SIZES

Difficulties Encountered.—Many diemakers and even some tool engineers believe that the time spent in computing blank sizes for drawn shells is wasted. They say that the results obtained are not commensurate with the effort expended; that the computed blanks are not sufficiently accurate for practical use; and that the blank sizes for drawn shells must finally be developed in the shop anyway, and it is useless to attempt figuring them.

The facts are that, while some of these criticisms may be well taken, most of them are not quite fair. The size and shape of many an intricate blank as supplied by the tool designers may not always be exactly right, but they nevertheless give the diemaker something definite to start from, and constitute a good beginning toward developing his necessary trial blanks.

Oversize Blanks Are Often Advantageous.—Most computed blank sizes prove to be too large in practice. This is a good fault because shells are generally trimmed around the top, and the shell walls may be drawn too high at some places and too low at others. This may occur even though the punch is properly centered in the die. It is due to hard or soft spots in the sheet.

Many shells must have extra wall heights or flanges for false or real wiring, curling, or seaming. Another favorable feature in oversize blanks is that the shells draw better. If an extra flange of metal still remains on the die face and under the blankholder after the shell is drawn, the work will hug the punch closely around its top. This ensures greater accuracy in the sizes of the shells and more evenly drawn work. Of course, if shells are drawn down through the die, or are "pinch-trimmed," all the excess metal is wasted.

Causes of Oversize Shells.—Oversize blanks may not always be the cause of drawing shells too high. The fault may be in the die or in the material used, or it may be some one or a combination of the following troubles. (1) The metal may be ironed thinner than its original gage size. (2) The drawing radius may be too small. (3) The blankholder grip may be restricted. (4) Material may not be properly annealed. (5) The wrong lubricant may have been used. (6) Temper of the material may be lower than its resistance to "flow." In most

of these cases the metal will stretch too much and a surplus will remain after the draw. Light-gage materials will stretch more than the heavier gages. This stretching of shells may lead us to believe that the blank is too large. However, this conclusion is often incorrect. The real cause is that the blank area is not being properly utilized.

Predetermining Blank Sizes Is Necessary.—But aside from all this, the commonly used methods and formulas for determining shell blank sizes are highly useful. Without this knowledge, contract shops would be unable to estimate the costs of blanking and drawing dies. They could not safely arrive at the cost of a blanking or drawing die, the pounds of stock required per thousand blanks, the necessary size of the press, and the probable hourly output, unless they could ascertain the approximate blank size.

Theory for the Computation of Blank Sizes.—Blank sizes are computed on the theory that the material thickness will undergo no perceptible change after being transformed into a drawn shell, and that the area of a finished shell must therefore be equal to the area of the blank from which it is made. Diameters are determined by the distance between the center lines of the opposite walls of the shell. In other words, the diameter of a shell is its outside diameter minus the thickness of its wall.

Many of the commonly used blank formulas for cylindrical shells are based on the well-known equation that the blank diameter D, for a square-cornered shell (Fig. 200), is $D = \sqrt{d^2 + 4dh}$. Values for d and h are found by completing the square and transposing terms: $d = \sqrt{(D^2 + 4h^2)} - 2h$, and $h = (D^2 - d^2)/4d$.

When, as stated above, the areas of the blank and shell are equal, the origin of these formulas is apparent. If A represents the area of either the blank or shell, then, for a circular blank, $A = \frac{1}{4}\pi D^2$, and for the shell, $A = \frac{1}{4}\pi d^2 + \pi dh$. Therefore, $\frac{1}{4}\pi D^2 = \frac{1}{4}\pi d^2 + \pi dh$, and, dividing both sides of this equation by $\frac{1}{4}\pi$, we have $D^2 = d^2 + 4dh$, or $D = \sqrt{d^2 + 4dh}$. From $A = \frac{1}{4}\pi D^2$, we find that $D = 1.128\sqrt{A}$ and that $A = D^2/1.273$.

Checking Formulas for Cylindrical Shell Blanks.—The centrobaric method of mathematical computation refers in part to the system employed for locating the center of gravity in lines and objects. It determines the areas and volumes of solids by considering their forms as generated by a line, or a surface of the form, which rotates about a fixed axis. Similarly, the theorem of Pappus* is founded upon the

* Pappus of Alexandria was a Greek mathematician and writer who lived in the third century. The theorems on centers of gravity usually attributed to Guldinus, and the centrobaric method, were originally due to Pappus.

principle that, if the length of any given line, h in Fig. 188, is revolved in a plane parallel with an axis X-X, by a given radius R, at right angles to the axis and touching the center of gravity in the line, the line will generate, in one revolution, an area equal to its length multiplied by the circumference traced by the center of gravity.

Either the centrobaric method or the theorem of Pappus is useful in computing the areas of cylindrically drawn shells. Having the area of a shell, its corresponding blank diameter or $D = 1.128\sqrt{\text{area}}$. These computations and formulas are convenient because by using them the area of a finished shell can easily be found from the given print dimensions. If $D = 1.128\sqrt{\text{area}}$, and the area of any tubular section of a shell is $d\pi h$, then

$$\begin{aligned} 1.128\sqrt{\text{area}} &= 1.128\sqrt{d\pi h} \\ &= \sqrt{4dh} = 2\sqrt{dh}. \end{aligned}$$

A practical example of the above is seen in Fig. 189. Here, the finished shell at J is first separated into its component sections, as at K, L,* M, and N. According to the formula $2\sqrt{dh}$, we have

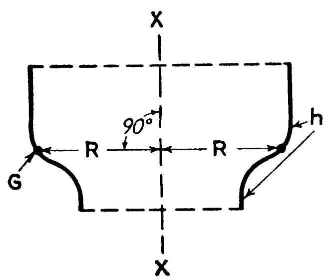


FIG. 188.

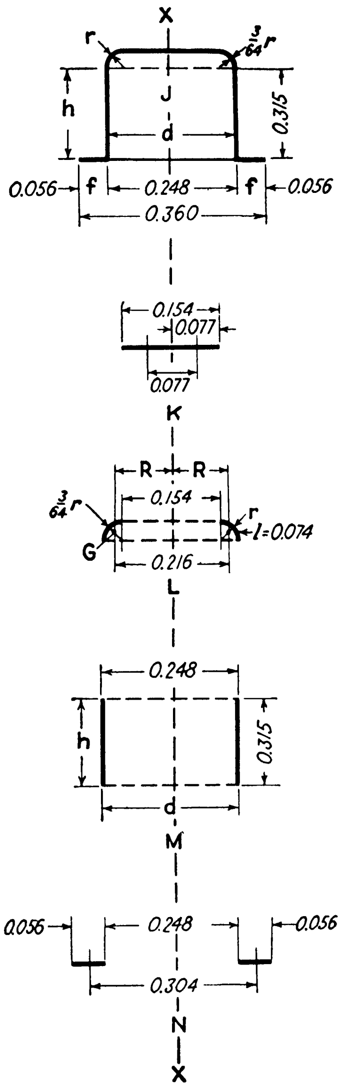


FIG. 189.

the following solution: Multiply the distance, or length of diameter between the centers of gravity, by the length of the contour line involved in each section, total these products, extract the square root,

* At L the diameter between the centers of gravity G for exterior arcs is $1.273r + 0.154$, and the length of arc $l = 1.5708r$.

and multiply by 2. This operation gives the blank diameter of the shell. The following example refers to Fig. 189.

$$\begin{aligned}
\text{Section } K &= 0.077 \times 0.077 = 0.00593 \text{ in.}\\
\text{Section } L &= 0.216 \times 0.074 = 0.01599\\
\text{Section } M &= 0.248 \times 0.315 = 0.07812\\
\text{Section } N &= 0.304 \times 0.056 = 0.01702\\
\text{Total} &\qquad\qquad\qquad\quad = 0.11706 \text{ in.}
\end{aligned}$$

$$D = 2\sqrt{0.1171} = 0.6845 \text{ in.}$$

By comparing the above solution with the standard formula given for this type of shell, we have

$$D = \sqrt{(d + 2f)^2 + 4d(h + 0.57r)} \quad \text{(See Fig. 217.)}$$
$$D = \sqrt{.36^2 + 0.992(0.315 + 0.027)}$$
$$D = \sqrt{0.468864} = 0.6847 \text{ in.}$$

The difference between the two results for D is a negligible quantity.

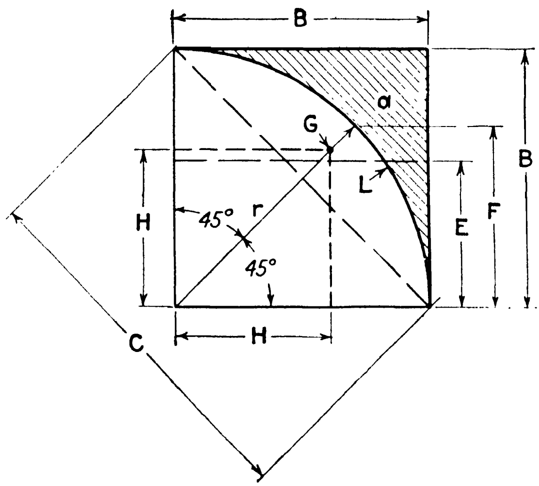


FIG. 190.—Square.

Area of Fillets.—From Fig. 190, several important formulas are derived which are useful in computing shell blanks. Entire area $A = B^2$. Area of fillet $a = 0.2146r^2$. Area of the quadrant $= 0.7854r^2$. Chord $C = 1.4142B$. Side $B = 0.70711C$. Length of arc $L = 1.5708r$. Center of gravity G, of arc L, $H = 0.6366r$. When $E + B = L$, then $E = 0.5708r$. $F = 0.70711r$.

Rectangles.—Figure 191. Entire area $A = BC - 0.8584r^2$. Area of sectioned portion, $a = (B - 2r)(C - 2r)$, or EF. Area of border $= 2r(E + F) + \pi r^2$. Length of diagonal $G = \sqrt{E^2 + F^2}$.

Figure 192. $H = 0.70711r$. Entire area $A = BC - \pi r^2$. Area of border $= 2H(B + E) - \pi r^2$. Area of inscribed rectangle

$$a = (B - 2H)(C - 2H) = EF.$$

Universal Formula for Cylindrical Shells.—In Fig. 193, for the blank diameter, first add around the top of E sufficient metal for sub-

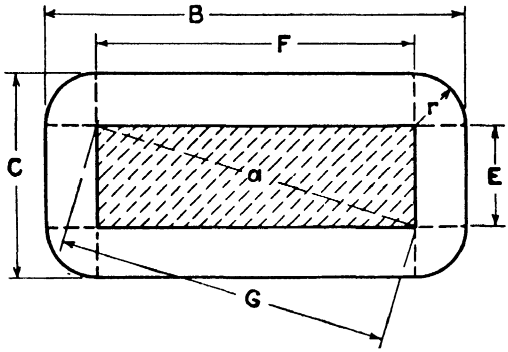


Fig. 191.—Rectangle with round corners.

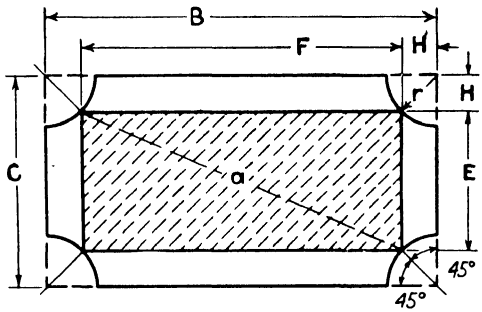


Fig. 192.—Rectangle with concave corners.

sequently trimming the shell. Then multiply the length of diameter between the centers of gravity G by the length of the outside contour line, for each of the sections. Next, total all these products, extract the square root, and multiply by 2. The result will be the blank diameter D for the shell. $D = 2\sqrt{BE + HL + ML + JL + CF + NL}$. To find G for the arc quadrants, see the formula given under Fig. 190. The above formula can be used in finding D for any contour of cylindrical shells.

Rectangular Shells.—Figure 194. $F = B - 2r$. $G = C - 2r$. $H = E - r$. Entire area

$$A = 2H(F + G) + GF + 6.283r\left(\frac{F + G}{2} + H\right) + 6.283r^2.$$

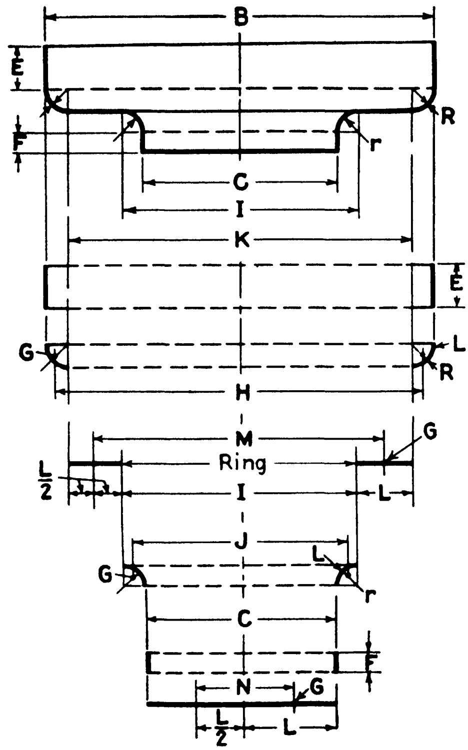


FIG. 193.—A shell segregated into its components.

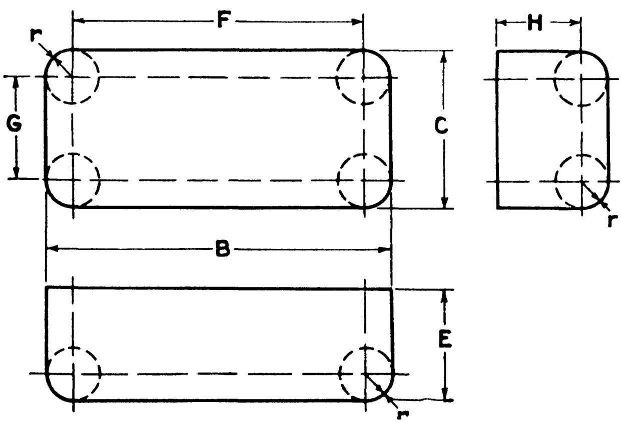


FIG. 194.—Rectangular shell with round corners of equal radii.

Figure 195. $F = B - 2r$. $H = E - r$. Entire area

$$A = 4HF + F^2 + 6.283r(F + H) + 6.283r^2.$$

Developing Blanks for Rectangular Shells.—Given the center lines within the walls of a rectangularly drawn shell, Fig. 196, to lay out the required blank. The finished shell is shown at L, and its approximate blank at M. First, ascertain the area of the finished shell by using the formula given under Fig. 194, and designate this area as a.

Next, lay out the rectangle J-K, with J equal to $2H$ plus G plus twice the lengths of the quadrants described by radius r; likewise K equals $2H$ plus F plus twice the lengths of the quadrants described by radius r. A formula for the lengths of quadrants is given under Fig. 190. From the area of the rectangle A, or $J \times K$, subtract the area of the shell, and divide the difference by 4. The quotient thus obtained shows how many square inches of metal must be removed from each corner of the rectangle in order to make the areas of the blank and shell equal. Lay out a dotted plan view of the finished shell, symmetrically positioned within the center of the rectangle, as shown.

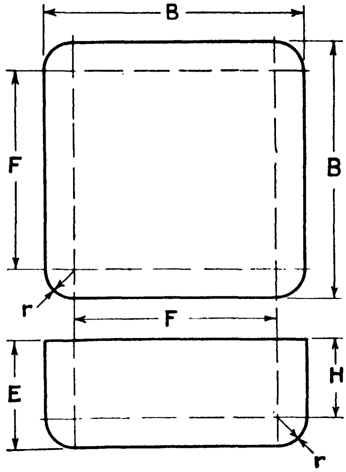


FIG. 195.—Square shell with round corners of equal radii.

It has been found in practice that the following procedure gives a very close approximation for cutting off the corners of the rectangle, to obtain equal areas for blank and shell and at the same time produce a shape that will draw up the corners of the shell practically correct.

Draw line O-P, at the lengths of lines N, in which

$$N = 0.707 \sqrt{A - a}.$$

Radius $R = (J - G)/2$. Using R, describe two arcs tangent with line O-P, and tangent with the side and end of the rectangular border lines. The result is seen at each of the four corners of the blank.

To check the work, determine the blank diameter D for the cylindrical shell having a hemispherical bottom, as seen at H. The formula for this blank is given under Fig. 202. Using the radius of this blank and the center r, describe the blank diameter D, as shown.

The perimeter of the blank should cut across line *O-P*, at a height *Q*, which is approximately equal to *D*/32.

It is always advisable, in constructing drawing dies for round-cornered square and rectangular shells, to make the spaces between the punch and die, around the corners, about 0.005 in. less than the

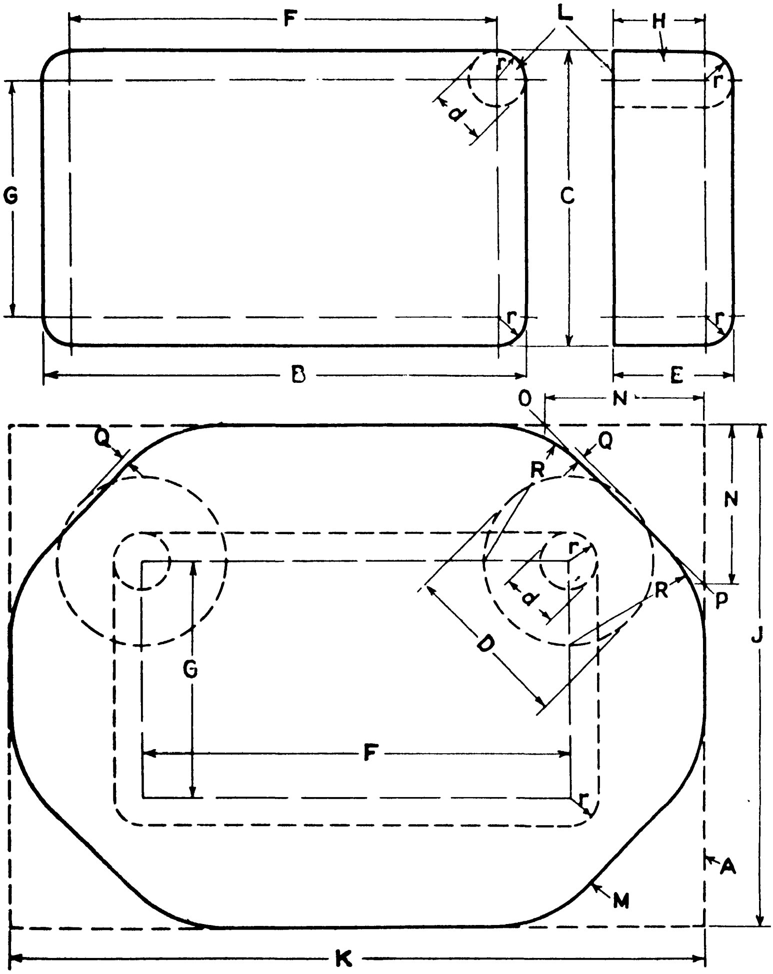


Fig. 196.

sheet-material thickness. This feature crowds the metal at the corners and causes it to draw higher, but the space can be decreased easily if the metal draws too high. This reduced space between the punch and die around the corners is considered as a precautionary measure. It often helps the toolmaker out of a bad situation, if this space happens to be too large.

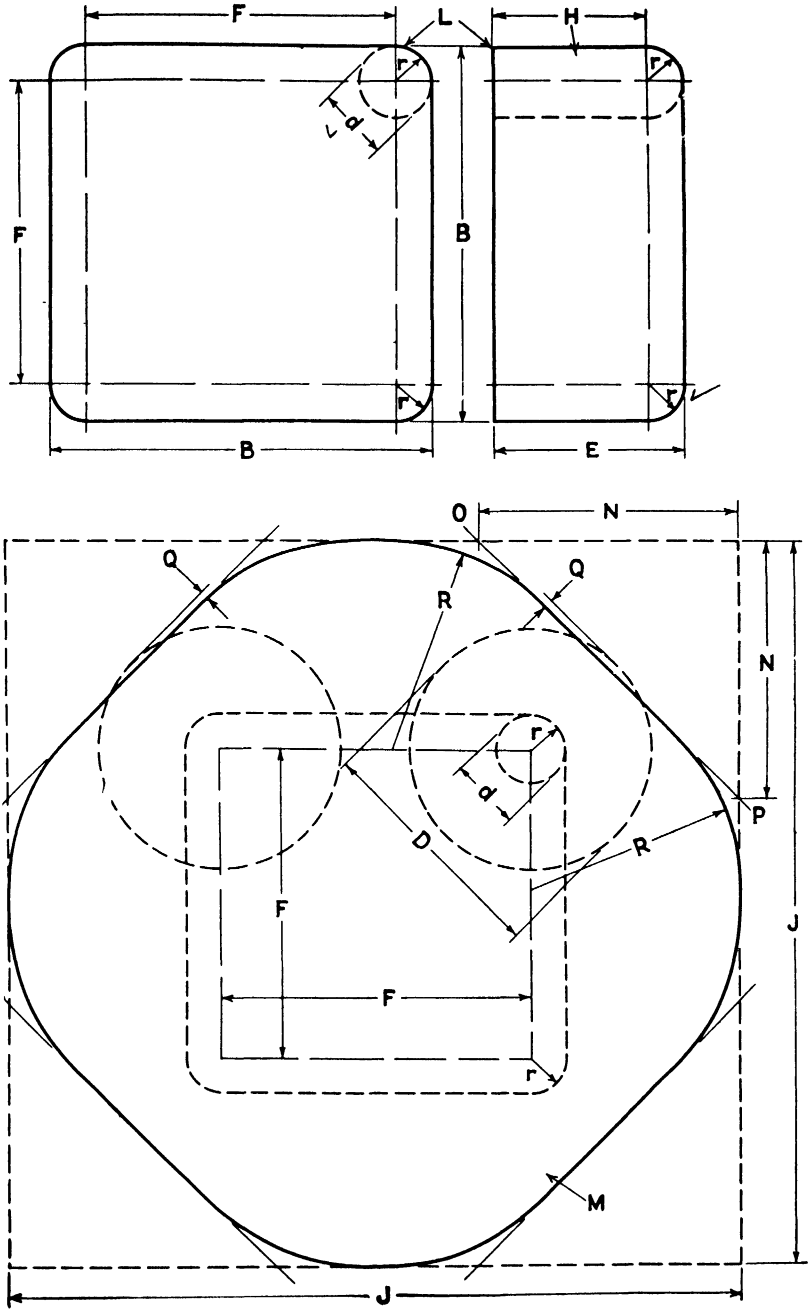


FIG. 197.

Developing Blanks for Square Shells.—The procedure for laying out blanks for square shells having rounded corners, Fig. 197, is the same as that used for rectangular shells, except that dimensions *G* and *K* are omitted because the shell and blank each have four equal sides. However, when rectangular, square, or near square shells have depths equal to or greater than their widths, the regular procedure for laying out of blanks must be changed somewhat. The changed method follows.

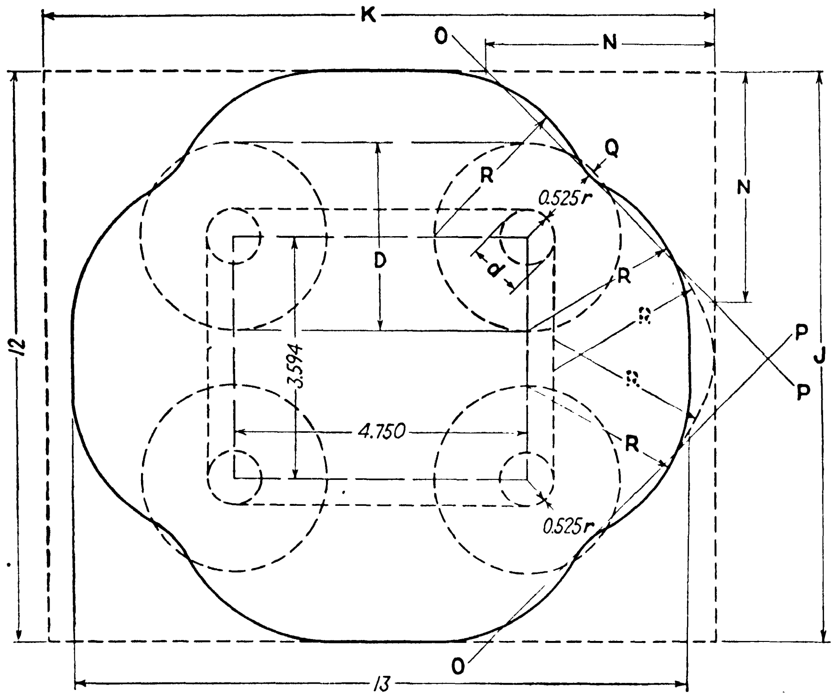
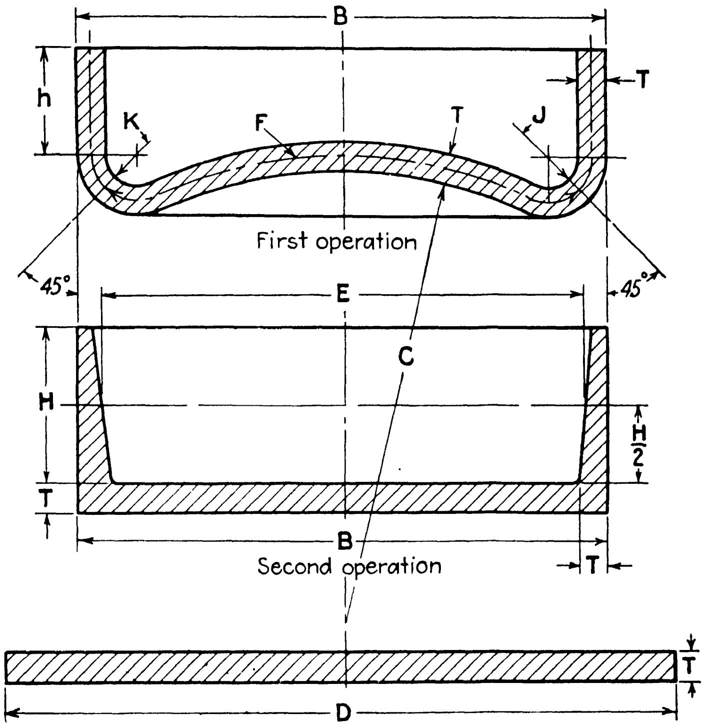


Fig. 198.

Laying Out Blanks for Deep-drawn Rectangular Shells.—When the depth of a finished rectangular shell approaches, equals, or is greater than its width, it is found that radius *R*, when drawn tangent with line *O-P*, cannot be made properly tangent to border line *J* of the rectangle, as seen at the right in Fig. 198. The two radii *R* overlap and form a point. This fault reduces the blank area to a figure less than the finished area of the shell, and therefore it cannot be used. A case of this kind is illustrated in the sketch. This blank development is taken from practice. Its size and shape were developed by the toolmaker. It is for a steel shell, 0.050-in.-gage material, and for a width and length given on the sketch.

It is noticed that length K has been shortened to 13 in., and extra metal has been added by radius R to maintain the equality between the blank area and that of the finished shell. Before this layout was made, $\frac{1}{4}$ in. of extra metal was added to the finished height of the shell all around its top. This allowance is for subsequently trimming the shell; a similar allowance should always be made before starting any blank developments for shells.



Blank

Fig. 199.

Producing Square-cornered Shells.—When drawing any type of shells, the least radius of the outside corner is necessarily two or more times greater than the thickness of its wall. This is because the radius around the nose of the drawing punch must be greater than the thickness of strip, otherwise wrinkles may appear, especially when using stock thicknesses less than about twenty times the width, length, or diameter of the shell.

Fortunately, we can, with properly designed dies, draw, or swage, square-cornered shells by using second or third operations. These operations are accomplished by using what may be called the "hump

method," as illustrated in Fig. 199. A rather heavy gage of stock is required, say, about 1/8 in. thick and up. The parts so produced are brake drums, certain types of piston heads, and similar work in which square-cornered shells are essential. The first operation shell is drawn with large radial corners inside and outside, and with a prominent concaved indentation represented by radius C. Before beginning the second operation, the shells are thoroughly annealed. They are then pushed down into a flat-bottomed die having the same size opening as the first die. The edge around the nose of the punch has a small radius, and its face is flat.

The punch, in descent, flattens the hump down straight across the die, the die being very strong. The extra metal over the hump forces the corners of the shell into a highly compressed state of momentary plasticity, and, as the punch continues to descend, the metal is caused to "flow" into the sharp corners of the die. A hydraulic press is employed, of 200 tons capacity or better, according to the severity of the operation, and using the positive ejector mechanism in the press is necessary. An oversize allowance is made in the size of the shell for finishing the outside surfaces by grinding.

Determining Blank Diameters by Volumes.—The mathematics involved in Fig. 199 is simple. Volume V is the governing factor, T the material thickness, and D the blank diameter. All dimensions are in inches, and D is determined from the given dimensions in the second operation, which is the finished shell.

$$V = (0.7854B^2)T + 0.7854(B^2 - E^2)H$$

Then

$$D = \sqrt{\frac{V}{0.7854T}}$$

In the first operation shell, the length of the compound curved line from the lines J to K must be approximately equal to B, and thus a length for radius C is established. The height h will be whatever the volume of the blank will give in the first draw.

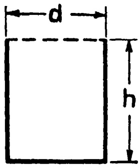
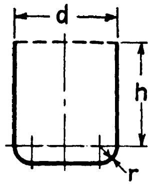
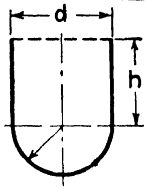
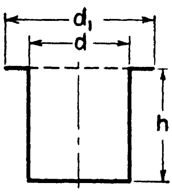
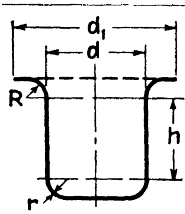
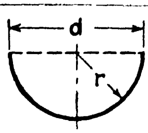
Determining Blank Diameters on a Lathe.—If the lathe hand will make the drawing punch first, and turn it accurately to the *outside* contour and diameters of the finished shell, and next clean the lathe of chips, he is then ready to find an accurate blank diameter by the volume method.

Next, he turns from the prepared punch the exact thickness of metal from which the shell is to be made, and catches all the chips under a hood placed over the work, the chips being delivered on a canvas spread under the work.

The last procedure is an easy one even though the shell has a very complicated contour. He simply weighs the chips and then divides the number of pounds (avoirdupois) by 0.2853, which is the weight of tool steel per cubic inch. The quotient is the volume of the shell walls in cubic inches. Having the volume V, the blank diameter $D = \sqrt{V/0.7854 \times T}$, in which T is the thickness of shell wall or material.

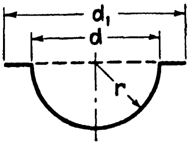
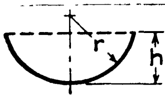
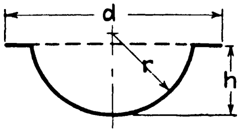
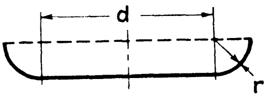
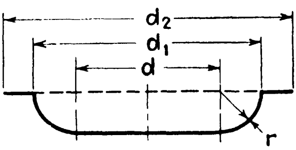
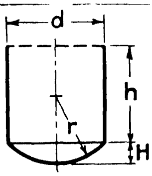
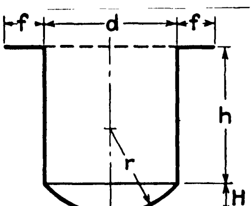
Of course, the shell height is turned $\frac{1}{8}$ to $\frac{1}{4}$ in. higher than the given print dimension, to allow metal for a subsequent trim around its mouth to complete the shell. This procedure presupposes that the volumes of the shell and of its blank are equal, which is true in most cases.

Formulas for Blank Diameters of Cylindrical Shells

 FIG. 200.	$D = \sqrt{d^2 + 4dh}$ for square corners
 FIG. 201.	$D = \sqrt{d^2 + 4d(h + 0.57r)}$ for round corners
 FIG. 202.	$D = \sqrt{d^2 + 4d(h + d/4)}$ also $D = 1.414\sqrt{d^2 + 2dh}$
 FIG. 203.	$D = \sqrt{d_1^2 + 4dh}$
 FIG. 204.	$D = \sqrt{d_1^2 + 4d(h + 0.57R + 0.57r)}$
 FIG. 205.	$D = \sqrt{8r^2} = 2.828r$, or $1.414d$

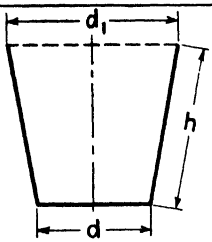
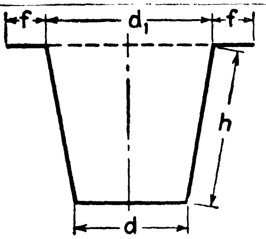
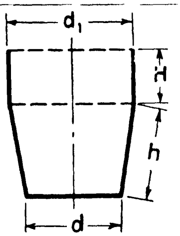
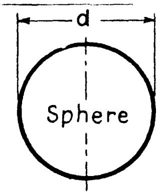
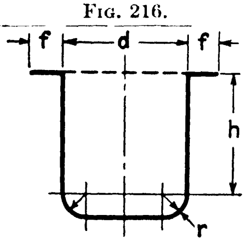
The area of a blank is $A = \dfrac{D^2}{1.273}$

Formulas for Blank Diameters of Cylindrical Shells

 FIG. 206.	$D = \sqrt{d^2 + d_1{}^2}$
 FIG. 207.	$D = \sqrt{8rh}$
 FIG. 208.	$D = \sqrt{d^2 + 4h^2}$
 FIG. 209.	$D = \sqrt{6.283rd + 8r^2 + d^2}$
 FIG. 210.	$D = \sqrt{6.283rd + 8r^2 + d^2 + (d_2{}^2 - d_1{}^2)}$
 FIG. 211.	$D = \sqrt{d^2 + 4(H^2 + dh)}$
 FIG. 212.	$D = \sqrt{(d + 2f)^2 + 4(H^2 + dh)}$

The area of a blank is $A = \dfrac{D^2}{1.273}$

Formulas for Blank Diameters of Cylindrical Shells

 FIG. 213.	$D = \sqrt{2h(d + d_1) + d^2}$
 FIG. 214.	$D = \sqrt{2h(d + d_1) + d^2 + (d_1 + 2f)^2 - d_1^2}$
 FIG. 215.	$D = \sqrt{d^2 + 2[h(d + d_1) + 2d_1H]}$
 FIG. 216.	$D = 1.128\sqrt{\pi d^2} = \sqrt{4d^2} = 2d$
 FIG. 217.	$D = \sqrt{(d + 2f)^2 + 4d(h + 0.57r)}$

The area of a blank is $A = \dfrac{D^2}{1.273}$

Formulas for Blank Diameters of Cylindrical Shells

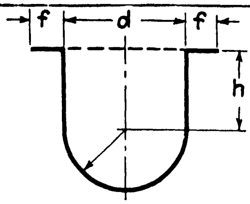


FIG. 218.

$$D = \sqrt{(d + 2f)^2 + 4d(h + d/4)}$$

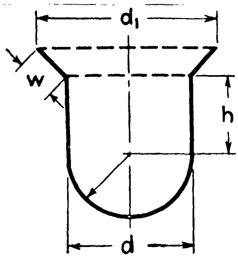


FIG. 219.

$$D = 1.414\sqrt{d^2 + 2dh + w(d + d_1)}$$

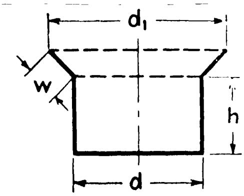


FIG. 220.

$$D = \sqrt{d^2 + 4dh + 2w(d + d_1)}$$

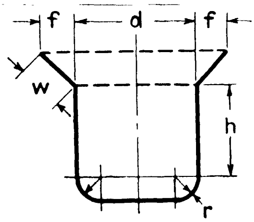


FIG. 221.

$$D = \sqrt{d^2 + 4d(h + 0.57r) + 4w(d + f)}$$

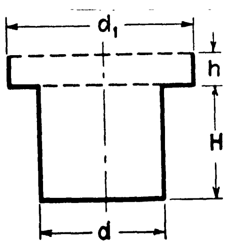
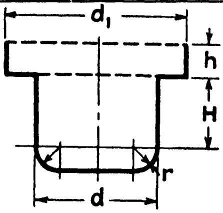
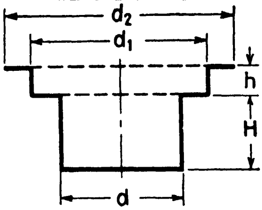
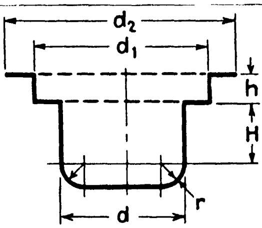
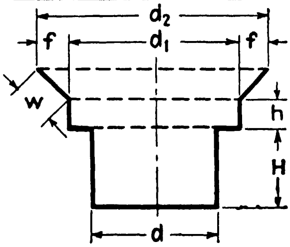
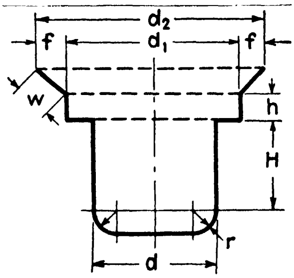


FIG. 222.

$$D = \sqrt{d_1^2 + 4(dH + d_1h)}$$

The area of a blank is $A = \dfrac{D^2}{1.273}$

Formulas for Blank Diameters of Cylindrical Shells

 FIG. 223.	$D = \sqrt{d_1^2 + 4d(H + 0.57r) + 4d_1h}$
 FIG. 224.	$D = \sqrt{d_2^2 + 4(dH + d_1h)}$
 FIG. 225.	$D = \sqrt{d_2^2 + 4d(H + 0.57r) + 4d_1h}$
 FIG. 226.	$D = \sqrt{d_1^2 + 4(dH + d_1h) + 4w(d_1 + f)}$
 FIG. 227.	$D = \sqrt{d_1^2 + 4[d(H + 0.57r) + d_1h] + 4w(d_1 + f)}$

The area of a blank is $A = \dfrac{D^2}{1.273}$

Formulas for Blank Diameters of Cylindrical Shells

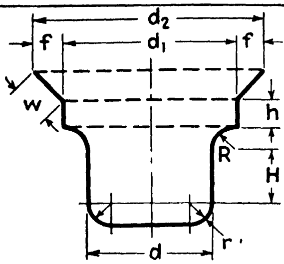


FIG. 228.

$$D = \sqrt{d_1^2 + 4[d(H + 0.57r + 0.57R) + d_1h] + 4w(d_1 + f)}$$

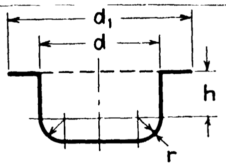


FIG. 229.

$$D = \sqrt{d_1^2 + 4d(0.57r + h) - 0.57r^2}$$

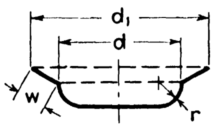


FIG. 230.

$$D = \sqrt{d^2 + 2.28rd + 2w(d + d_1) - 0.57r^2}$$

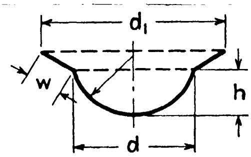


FIG. 231.

$$D = \sqrt{d^2 + 4h^2 + 2w(d + d_1)}$$

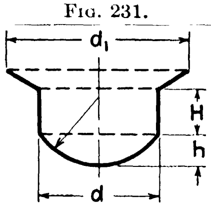


FIG. 232.

$$D = \sqrt{d^2 + 4[h^2 + dH + 0.5(d + d_1)]}$$

The area of a blank is $A = \dfrac{D^2}{1.273}$

Formulas for Areas of Shell Parts

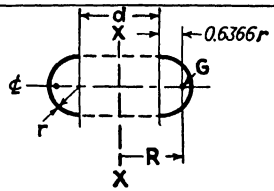


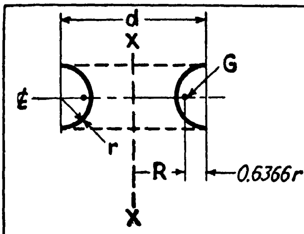
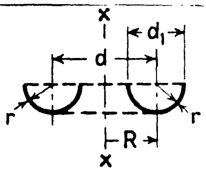
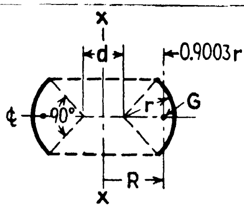
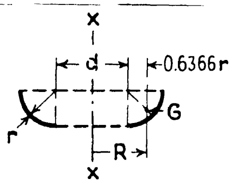
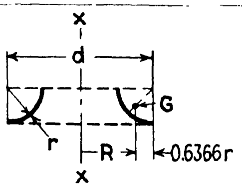
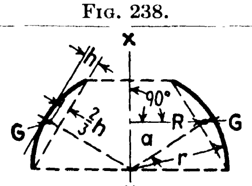
FIG. 233.

Exterior Semicircular Arcs, when G Is the Center of Gravity of the Arcs, and l Is the Length of Arc,

$R = \dfrac{d}{2} + 0.6366r \qquad A = 6.283Rl$

l = length of arc. Blank diameter $D = 1.128\sqrt{A}$

Formulas for Areas of Shell Parts

 FIG. 234.	*Interior Semicircular Arcs* $R = \frac{d}{2} - 0.6366r \qquad A = 6.283Rl$
 FIG. 235.	*Horizontal Semicircular Arcs* *One-half of a Wiring Ring* $R = \frac{d}{2} \qquad A = 6.283Rl$ Also $A = \frac{9.87dd_1}{2}$
 FIG. 236.	*Vertical Circular Arc Quadrants* $R = \frac{d}{2} + 0.9003r \qquad A = 6.283Rl$
 FIG. 237.	*Exterior Circular Arc Quadrants* $R = \frac{d}{2} + 0.6366r \qquad A = 6.283Rl$
 FIG. 238.	*Interior Circular Arc Quadrants* $R = \frac{d}{2} - 0.6366r \qquad A = 6.283Rl$
 FIG. 239.	*Circular Arcs Less than Quadrants, and Symmetrically Positioned at Any Angle to Axis $x - x$* $R = \left(r - \frac{h}{3}\right) \cos a \qquad A = 6.283Rl$

l = length of arc. Blank diameter $D = 1.128\sqrt{A}$

Diagrams Determine Blanks for Cylindrical Shells.—Blank diameters for all the standard shapes of round shells can be solved by constructing simple diagrams. This can be done by laying out plain geometric figures. Either the engineer or toolmaker makes the layout, the latter using a pair of dividers on a sheet of metal. This method is more interesting than is the use of formulas because it eliminates mathematics and substitutes mechanical skill. Nine of such developments are given in Figs. 240 to 249, inclusive.

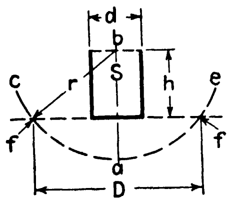


FIG. 240.—Make an accurate layout of the shell S, on center line a-b, full size if shell is large, five or ten sizes if it is small. With b as the center and with r equal to h plus $d/2$, scribe arc c-e. Extend bottom line of the shell horizontally, cutting arc c-e at points f-f; then D is the required diameter of the blank. $D = \sqrt{d^2 + 4dh}$.

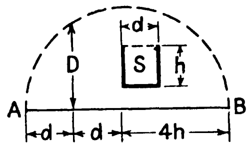


FIG. 241.—Another method for solving the preceding problem is to draw the horizontal line A-B, with its length equal to $2d$ plus $4h$. Scribe a semicircle on line A-B, using it for the diameter. From point A, lay out distance d on line A-B and at d erect the perpendicular line D, touching the arc; the length of line D is the required diameter of the blank for shell S. $D = \sqrt{d^2 + 4dh}$.

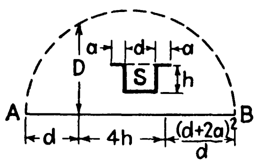


FIG. 242.—Here shell S has square corners and a flanged mouth. Draw horizontal line A-B with its length equal to the dimensions shown. Scribe a semicircle on line A-B, using it for the diameter. From point A lay out distance d on line A-B, and at d erect the perpendicular line D, touching the arc; the length of line D is the required diameter of the blank. $D = \sqrt{(d + 2a)^2 + 4dh}$.

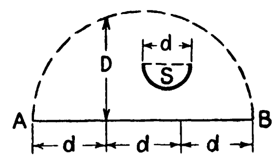


FIG. 243.—For the hemispherical shell shown at S, the diagram laid out as seen in the sketch gives the blank diameter. $D = \sqrt{2d^2} = 1.414d$.

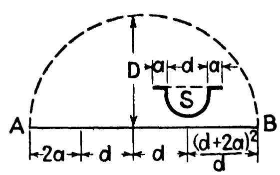


FIG. 244.—For the hemispherical shell at S, having a circular flange a, the diagram laid out as shown in the figure gives the blank diameter. $D = \sqrt{(d + 2a)^2 + d^2}$.

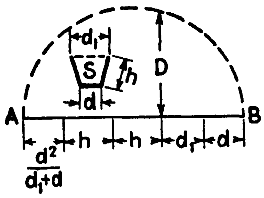


FIG. 245.—The blank diameter D for the truncated cone shell S can be determined by laying out the diagram shown. $D = \sqrt{2h(d + d_1) + d^2}$.

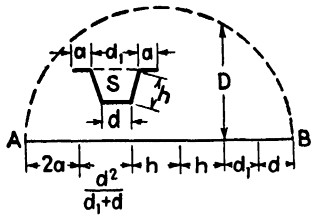


FIG. 246.—The truncated cone shell S, having the circular flange a, has a blank diameter D, which is determined by the given diagram.

$D = \sqrt{2h(d + d_1) + d^2 + (d_1 + 2a)^2 - d_1^2}$

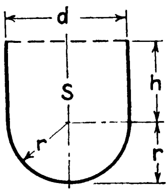


FIG. 247.

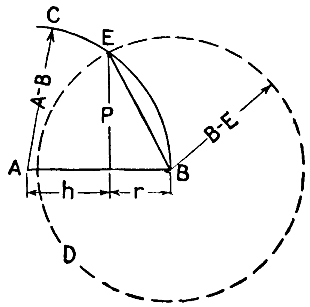


FIG. 248.

Figure 247 is a round shell S with a hemispherical bottom whose blank diameter D is determined by the diagram in Fig. 248. Draw horizontal line A-B equal in length to $h + r$. Using point A as a center, and with A-B for the radius, describe the indefinite arc B-C. From A locate distance h on line A-B, and at that point erect the perpendicular line P, touching arc B-C at E. With point B as a center and B-E for a radius, describe circle D, which is the required blank diameter.

$$D = 1.414\sqrt{d^2 + 2dh}.$$

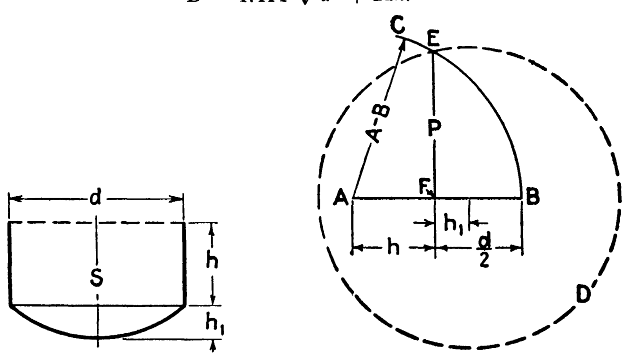


FIG. 249.—Shell S has a spherical segment bottom. Draw the horizontal line A-B equal to $h + d/2$. With point A as a center and A-B the radius, describe the indefinite arc B-C. From point A locate distance h on line A-B at F. At F erect the perpendicular line P, touching arc B-C at E. From the right of point F lay out distance h_1 on line F-B and, using this point as a center with a radius passing through E, describe circle D which represents the blank diameter.

$$D = \sqrt{d^2 + 4(h_1^2 + dh)}.$$

CHAPTER XI

FABRICATING AIRCRAFT PARTS

Introduction.—There are two outstanding processes employed in the mass production of certain aircraft parts, and each is comparatively new. The most important one is the patented Guerin process, which can be used with mechanical presses but is usually employed in large hydraulic presses. The other process is done in a new type of hydraulic machine called a "stretching press" (see Fig. 250).

In the Guerin process light metal parts are blanked or formed under the pressure of a soft rubber pad. The blank to be formed is positioned over a punch, die, or other forms that lie on the anvil of a hydraulic press. The pressing platen, in which the soft rubber pad is compressed and retained, then descends upon the blanks and the rubber expands, thus forming the parts over the punches or dies. Many different shapes of work may be fabricated simultaneously in one press stroke.

Special materials are used in the construction of the dies or forms. One of these materials is Masonite, which is an easily worked plastic composition practically impervious to moisture, and another is known as Kirksite "A," which is a zinc alloy that may be cast; it is hard and tough. Both of these materials can be easily machined.

A reproduced photograph of a master rubber pad installed within its container is shown in the view of a hydraulic press platen on Plate V, page 308. A representative type of a stretching press is seen in Fig. 250. These two processes are used in fabricating aircraft parts which, by any other known method, would be very difficult and expensive to produce—for example, large parts of streamlined sections, parts for large gasoline tanks, door frames, edge ribs, cowling segments, corrugations, and sections of compound arcs.

Besides these two processes, thousands of other parts for completed airplanes are fabricated by well-known conventional methods, such as in drop-hammer and ordinary punch presses. As in automobile manufacture, many parts are cast or forged and some are made from commercial shapes. This suggests the use of milling, turning, spinning, drilling, welding, assembling, swaging, cold-sizing, and plating operations. These operations involve the designing and building of many such well-known types of tools as dies, jigs, fixtures, and

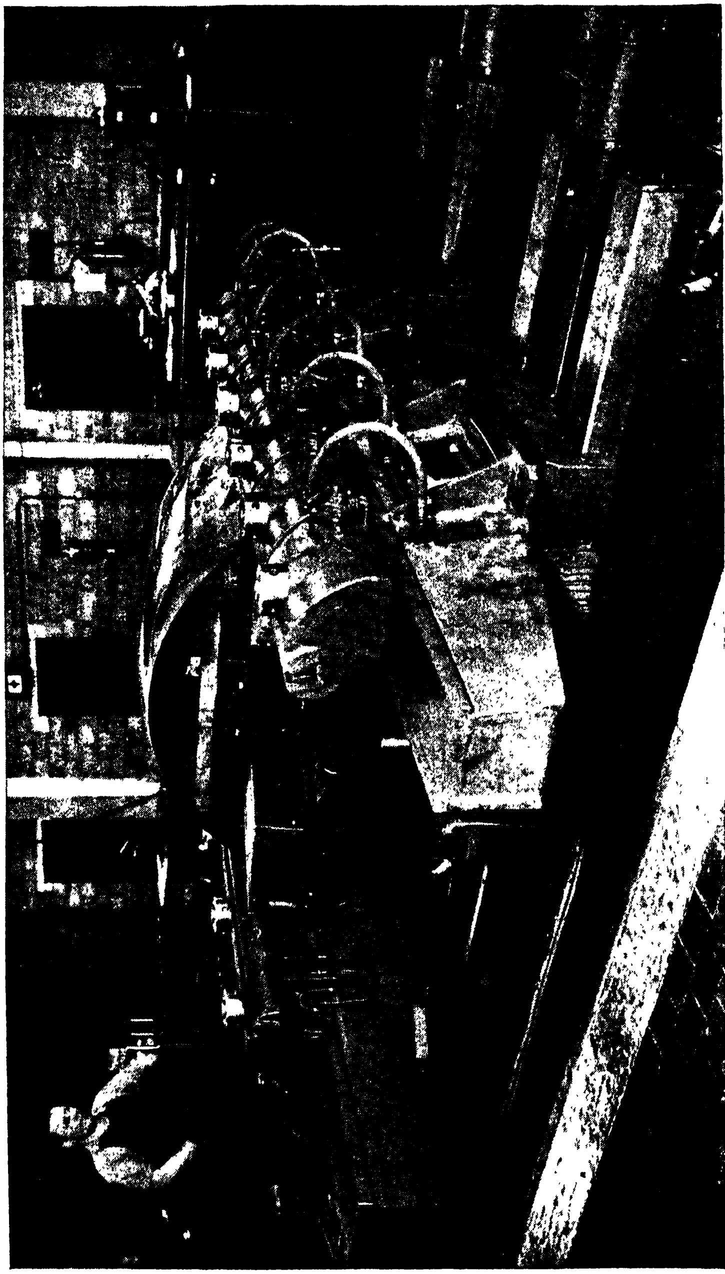


FIG. 250.—Typical stretching press shaping a sheet of metal. Parts formed are streamlined sections for aircraft "skins" and for automotive work such as corner sections for bus bodies. The punch is operated vertically by a hydraulic cylinder under the press, as shown. The forming punch is composed of Masonite blocks. This view was taken in the plant of Grumman Aircraft Engineering Corporation.

special machinery. Obviously, these conditions call for thousands of highly skilled engineers, tool designers, diemakers, machinists, and machine operators. Practically every known trade is represented in the general personnel of any large aircraft plant.

The Guerin Process.—Primarily this process was developed for the purpose of fabricating very ductile metals such as aluminum and magnesium alloys, but it is now successfully used in forming light gages of Stainless and mild steels within a limited range of shapes. Certain features make this process adaptable for the manufacture of a wide variety of such commercial products as furniture, cabinets, and household wares.

Types of Master Rubber Pads.*—In order to accommodate a maximum range of parts, the depth of the master rubber pad should be not less than 10 in., and the container into which it fits should be at least 2 in. deeper, thus permitting 2 in. of indexing space within the pressing platen before the master pad makes contact. The clearance between the container and the pressing platen after indexing occurs should be kept to an absolute minimum, preferably not over $1/32$ in., so as to retain the rubber and prevent dissipation of power by extrusion. Not only would extrusion of the master pad result in considerable loss of power, but the edges of the pad itself would very soon break down. (See Plate V, page 308.)

There are in use at present two main types of master rubber pads, laminated or "built up," and homogeneous. The majority of the pads used thus far have been of the laminated type. These are usually built up from 1-in. laminations and vulcanized one to another until the required thickness has been obtained. This type of pad has proved very satisfactory, providing adequate loading precautions are taken to prevent separation of the laminations and subsequent disintegration of the pad. Recently a new type of master pad has come into use. This is a homogeneous mass of rubber which is cured in a single molding and has no laminations. Its use, however, has not been sufficiently extensive to warrant comments upon its advantages or disadvantages, at this time.

For ideal formability and maximum longevity, the master pad must possess extremely high elasticity and at the same time be sufficiently hard to resist compression which is developed by the many parts being formed. This, of course, necessitates a compromise but experience has proved that a pad with a Shore Durometer hardness of 60 (plus or minus 5) with a Shore elasticity of 75 to 80, provides the best

* M. G. Simpson, process engineer, Douglas Aircraft Company, in *The Modern Industrial Press*.

forming characteristics and at the same time ensures maximum pad life.

A considerable amount of auxiliary rubber is used in conjunction with the Guerin process. This rubber is ordinarily purchased in the form of blankets or pads approximately 24 by 24 by 1 in. and of three different types, sponge, live, and hard. However, it may be bought in rolls and cut to any desired size. There are several reasons for using this auxiliary rubber, among which are: the concentration of pressure on localized areas to assist in forming beads, lightening holes in flanges, etc., and to achieve a free wrap-around action which is not entirely possible with the master pad itself because of the tremendous amount of shear resistance within it.

Dies for Guerin Process.—In designing dies the materials from which to choose are inexpensive. The materials most widely used are

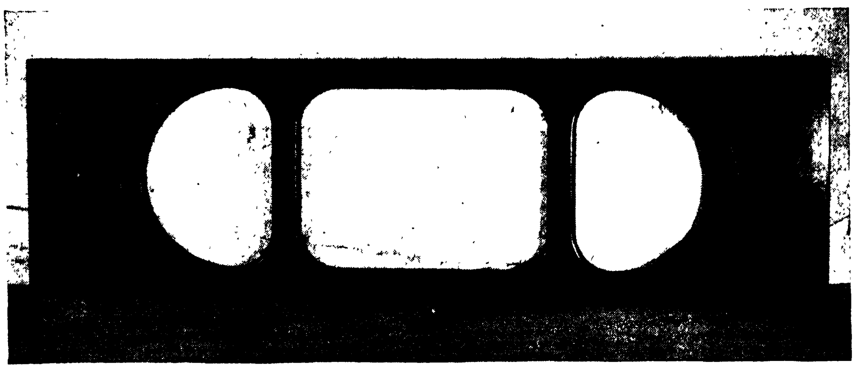


FIG. 251.—A Masonite die block used in forming aircraft window panels at Vought-Sikorsky Aircraft plant.

Masonite, aluminum alloy, zinc alloy, and in some instances steel, magnesium, and certain types of plastic. The newly developed Masonite die stock is an economical die material not only from a cost standpoint but also because it can be fabricated easily into a finished die. It may be worked with standard woodworking tools and is usually shaped by means of high-speed router cutters. Masonite dies are very satisfactory for forming parts that require little or no handwork. However, owing to the laminated construction of this material, very little hammering can be done on it without harmful effects. Therefore, when a part requires considerable handwork after forming, the die must be of aluminum or some other material capable of withstanding severe impact.

An outstanding advantage of Masonite as a die material is its light weight. This permits using a minimum of power equipment for

moving and handling of dies. The ease with which Masonite can be worked makes it possible to use an unlimited amount of detail on the face of the die for stiffening the die members, ornamentation, etc. Such detail is required in numerous parts, and material such as Masonite lends itself well for the tooling required, as shown in Figs. 251 and 252.

Aluminum alloy plate stock of a heat-treated variety has proved to be a valuable die material for parts of such severe draws and forming that considerable handwork is required to complete the part after the operation. It is also used to advantage for dies having a cross section

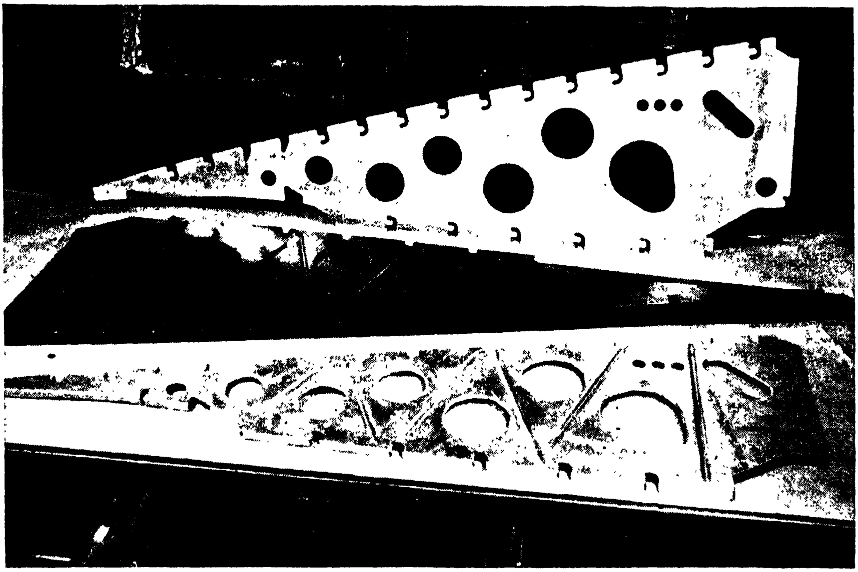


FIG. 252.—A trailing-edge rib with its respective forming die. The piece at the top is a blank before forming and the formed piece is the one in the foreground. The die used is made from a Masonite block. (*Courtesy of Douglas Aircraft Company.*)

so small as to require a strong material capable of withstanding the uneven forces to which they may be subjected. The machinability of aluminum alloy is exceptionally good, and it can be finished with a minimum amount of work as compared with steel. Aluminum alloy has a satisfactory scrap value when the tool becomes obsolete, thereby reducing the original tool cost.

Zinc alloy is used in the construction of large dies where casting is necessary. It also has the advantage of being redeemable upon the obsolescence of the die, as it can be recast into a new tool. Zinc alloy, after casting, requires a small amount of grinding and polishing in order to prepare the finished die. This material is also used for blank-

ing formed parts of complicated design. In this case, a shear edge is cast upon the die, and the edge is sharpened. As many as 1,000 parts have been blanked on this type of die before resharpening became necessary.

Although zinc alloy dies have been used successfully in hot-forming magnesium sheet, it has been found advisable to use magnesium dies for this purpose. The reason for using a die of the same composition as the material being formed are uniform thermal expansion and prevention of contamination. Added advantages are better heat conductivity and greater ease of handling because of lighter weight.

Steel may be used as a die material, but it is not recommended except in special cases where a large number of parts are to be fabricated, thus making possible the amortization of more costly dies. Not only is steel more difficult to work, but its scrap value is relatively low as compared with zinc or aluminum. The fact that a rubber pad is used in place of a mating die minimizes the die wear and makes it possible, in fact preferable, to use die materials with better machining characteristics, such as those previously mentioned.

Recent experiments have been made in the use of thermosetting plastics as a die material. These tests to date seem to promise some advantage from an operation standpoint. Among the advantages of plastic material are its light weight and the fact that it may be cast to any desired shapes. However, heat or pressure, or a combination of these two, is required in curing most casting resins, which, of course, means added expense and equipment. Although the advantages of plastic materials do not appear sufficiently outstanding to warrant their use at present, yet in the event of a severe shortage of zinc or other die materials, it may prove expedient to cast dies from plastic materials for the Guerin process.

How the Blanks Are Made.—There are several methods for cutting blanks before forming, and the selection of the proper method is usually governed by the degree of elongation to which the edges of the part will be subjected. The most commonly used methods are the router, the circle shear, or an inexpensive blanking die known as the "pierce blank template." Blanks up to 0.040 in. thickness are sometimes cut out on shear dies by means of the Guerin process. However, shearing blanks by this method is usually confined to combination form and shear operations such as the forming and blanking of certain "skins."

Flanges are classed as being either concave or convex, according to the following designations. The term "concave" is used to describe a flange which breaks away from a flat surface, along a curved line and

away from the center of the arc of curvature. The term "convex" is used to describe a flange which differs from the concave only in that it breaks toward the center of the arc of curvature. Whenever the part is to have concave flanges or free edges that must undergo considerable elongation, the blank is cut by the router method, which produces edges from which maximum elongation may be derived. Edges left by the routing machine require no finishing before forming.

If the edges of the part are not required to undergo severe elongation during forming, then the pierce blank template is an economical and expedient method which primarily is limited only by the size of the part to be blanked in relation to the bed of the punch press.

The circle shear produces comparatively rough edges, thus affording the least amount of elongation. However, this method is quite satisfactory for cutting out blanks that will normally require a finish trim after forming. Another method for cutting blanks is shown in Plate XXIV, page 431.

Classification of Aircraft Parts.—The various sheet metal parts encountered in aircraft fabrication cover a wide range of shapes, contours, and types. In analyzing the shapes most often formed by the Guerin process we find that they constitute three major types. The first and most common consists of flat planes with flanges which are either straight or curved. Many aircraft parts fall into this classification, typical examples being channels, braces, fuselage frames, floor frames, and wing ribs. In selecting the proper tools for fabricating channels and braces, we find that Masonite in most cases is a satisfactory die material. However, if there is either sufficient compression on a flange during forming to produce severe buckling, or an exceptionally narrow die cross section which might cause failure, it would be advisable to use a die material of sufficient strength to withstand the impact of necessary handwork and at the same time have a greater resistance to the deformation which may occur under certain operating conditions.

Forming Aircraft Parts.—Wing ribs usually incorporate both lightening holes and stiffener beads. The lightening holes in this case are formed and blanked simultaneously, provided the material is not over 0.040 in. thick. The only difficulty normally encountered in forming this type of part is the severe shrinkage that must occur around the curved nose section. However, this can be overcome by incorporating relieved openings or recessed scallops to eliminate puckering or buckling that would otherwise occur, as shown in Figs. 253 and 254. These recessed areas, however, must be located so as not to interfere with the attaching area of the flange. If either of

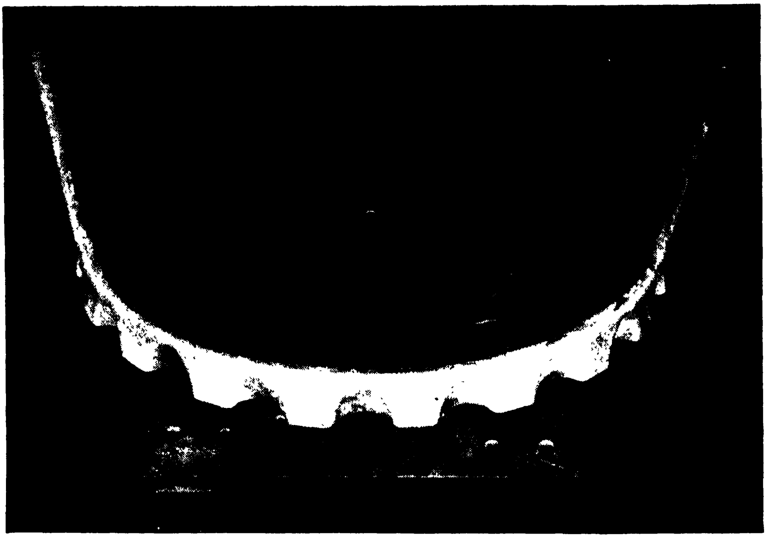


FIG. 253.—Illustrating how recessed scallops avoid gathering wrinkles in the edges of a piece when forming convex flanges by the Guerin process. (*Courtesy of Douglas Aircraft Company.*)

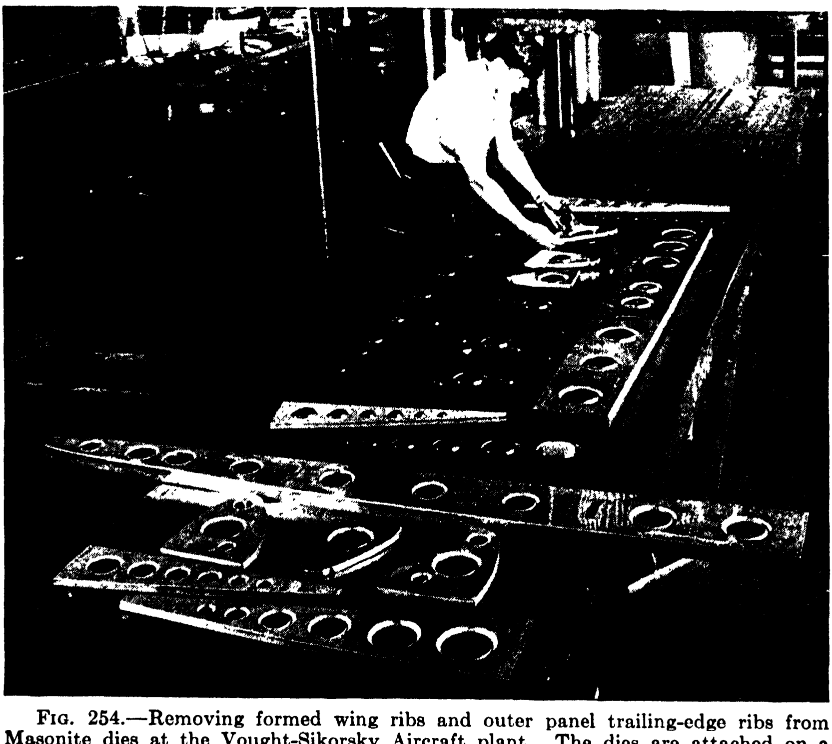


FIG. 254.—Removing formed wing ribs and outer panel trailing-edge ribs from Masonite dies at the Vought-Sikorsky Aircraft plant. The dies are attached on a plate that can be moved out of the press after the pieces are formed by the Guerin

these designs can be incorporated into the part, thus removing the necessity for handworking, a Masonite die is a satisfactory tool for manufacturing nose ribs. Blanking the lightening holes is accomplished in most cases by means of shear rings or shear plates which are made from commercial steel tubing or plate stock. These rings are allowed to "float" or self-index into the lightening hole during the forming operation, thus blanking out the lightening holes from within

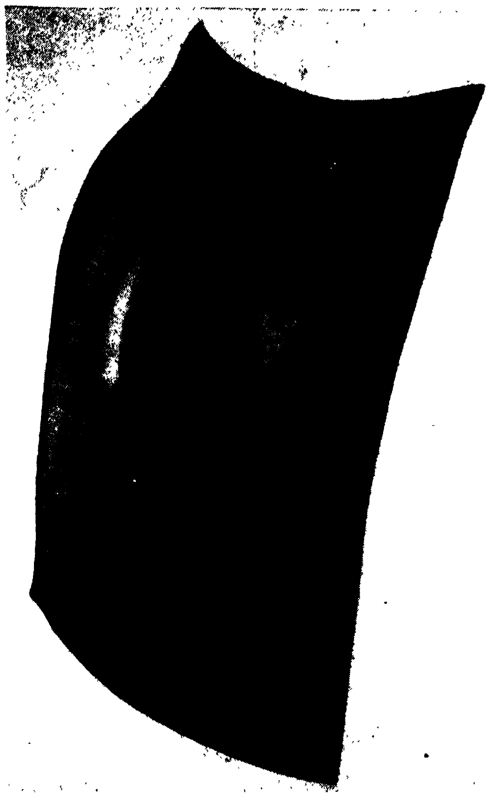


FIG. 255.—Cowling segment pretrimmed and prepared for a forming operation. (*Courtesy of Douglas Aircraft Company.*)

the web of the rib. Shear plates are held in position by a $\frac{3}{8}$-in. steel dowel pin located at the center point of the lightening hole.

The forming of compound curvatures in sheet metal is generally considered a difficult operation. However, the Guerin process is capable of forming many parts which fall within this classification. A few of these are wing-tip skins, vertical and horizontal stabilizer skins, cowling sheets, and nacelle door skins and door inner liners.

Wing-tip skins are formed on a zinc alloy die which incorporates a shear edge. By this method, the part can be formed and blanked by a single stroke of the press.

Cowling sheet, such as is shown in Figs. 255 and 256, is made in two separate operations. As many as five sheets may be formed at one time in the first operation, which consists of stretching the main

FIG. 256.—Shape of the cowling segment after the first forming operation. Note the edges left for a trimming line. (*Courtesy of Douglas Aircraft Company.*)

FIG. 257.—Cowling segment after the second and final trimming and forming operation in which the Guerin process is used. (*Courtesy of Douglas Aircraft Company.*)

body of the part to shape. The second operation completes the nose section by forming the remainder of the sheet into a reverse position over a male die, Fig. 257. The cost of the tooling required to manufacture this type of part is only a fraction of that required when formed by other methods such as draw press or drop hammer.

Comparing Guerin Process with Other Methods.—It might be well to enumerate here the outstanding advantages in using this process

as compared with other methods of manufacturing aircraft sheet metal parts.

1. Where engineering changes are involved, it provides a rapid and economical method of revising the tooling. In the case of a change in gage thickness, no tooling changes are required.

2. Parts may be formed in such a manner as to make them inherently rigid, thereby eliminating the need for stiffening ribs.

3. It is possible to form flanges to a closed bevel with no additional tool cost, whereas with any other machine method costly tooling would be required.

4. One machine is capable of fabricating a large number of parts simultaneously, the quantity and size being limited only by the size of the pressure equipment and number of pressing tables used.

5. Since forming of the most irregular shapes is very simple, the design of parts can follow the best procedure without restriction by shop-practice limitations.

6. Owing to the tooling simplicity, combining of parts is often possible, thus reducing the number of detail parts and lowering the cost. In one case, a spot-welded assembly consisting of 29 parts was replaced by a single part which was formed on a hydropress by means of the Guerin process.

7. Use of the resilient rubber master pad, which has a hardness value much lower than that of aluminum, precludes the possibility of scratching the sheet material being formed, thus reducing the possibility of rejects and corrosion.

8. Local distortion is eliminated and cold-working reduced to a minimum because of the uniformity of pressure transmitted through the rubber pressing pad. This minimizes the possibility of distortion during heat-treating.

9. In place of the usual set of mating dies, this process employs a single low-cost die and a rubber pressing pad, thus greatly reducing the time and expense involved in "tooling up."

10. All parts made on the same die are uniform and accurate and therefore interchangeable. In many cases, the indexing holes used to locate the parts during forming may be utilized to coordinate assemblies.

Forming Magnesium Blanks by Guerin Process.—Figure 258 shows two different shapes of magnesium blanks positioned over dies preparatory to forming. Notice that the arc to be formed at one corner of the right-hand blank has slotted reliefs provided to prevent wrinkles. Figure 259 shows the finished parts being removed after the rubber-incased pressing platen has descended and formed the

blanks down over the dies. Stiffening ribs are pressed into each of the parts, as shown.

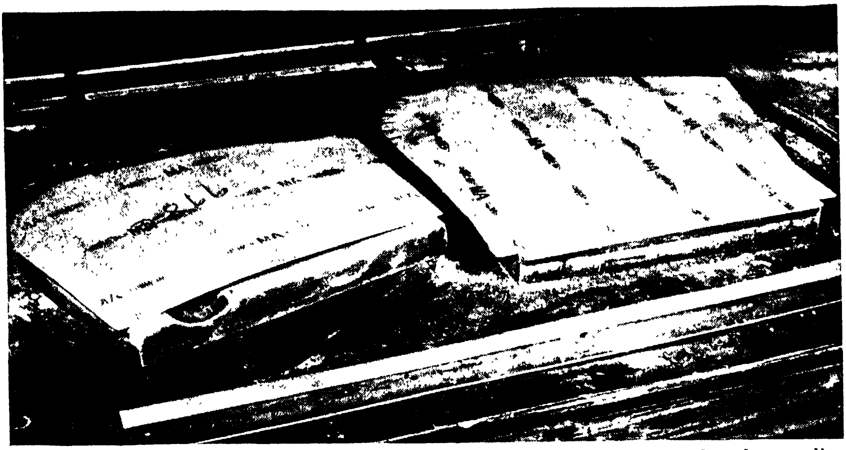


FIG. 258.—Aircraft blanks which have been cut from magnesium are placed over dies ready to be formed. (*Courtesy of Douglas Aircraft Company.*)

FIG. 259.—The blanks shown being removed from the dies after pressing and forming. (*Courtesy of Douglas Aircraft Company.*)

Typical Dies for Soft Rubber Forming.—Figures 260 and 261 show good examples of forming dies made from Masonite stock. This material can be easily shaped on woodworking machinery in the pattern shop. Dies for blanking are provided with shearing edges

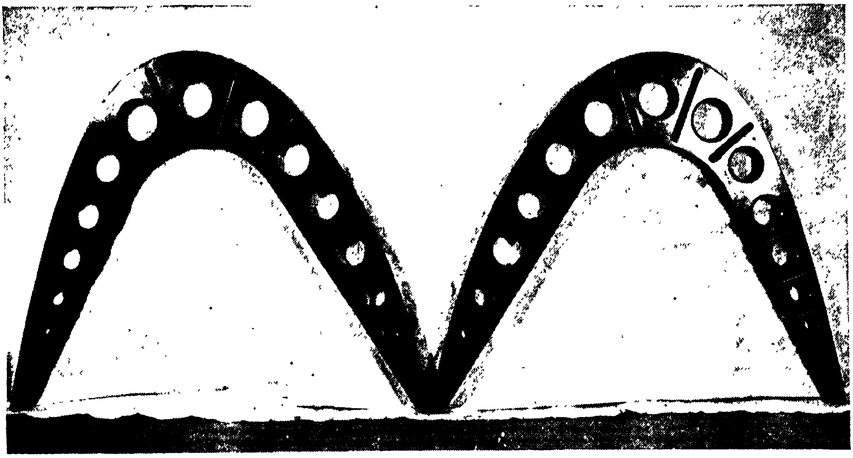


FIG. 260.—Masonite forming dies for leading-edge ribs. The 13 lightening holes can be cut in the work at the same time as forming because these dies are faced with 1/16-in. chrome-molybdenum steel. These dies were made in the pattern shop of the Vought-Sikorsky Aircraft plant.

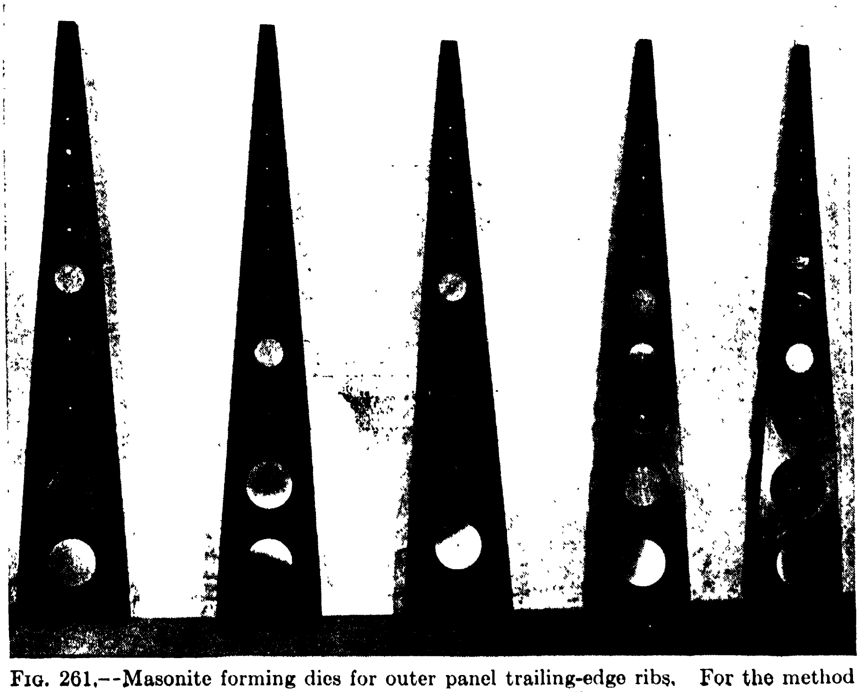


FIG. 261.—Masonite forming dies for outer panel trailing-edge ribs. For the method of using these dies in the presses see Fig. 254.

by mounting a $\frac{1}{16}$-in. surface plate of chrome-molybdenum steel on their faces. Masonite has the following physical properties:

Compression, plies in horizontal position	26,000 lb. per square inch
Compression, plies in vertical position	15,000 lb. per square inch
Modulus of rupture	15,000 lb. per square inch
Specific gravity (approximate)	1.33
Water absorption by weight, after 24 hours immersion	0.89 per cent
Weight per cubic inch	0.0480 lb.

By way of comparison, the specific gravity and weight are about the same as those for celluloid.

FIG. 262.—Putting the finishing touches on wing-rib forming dies of Masonite die stock at the Glenn L. Martin plant.

Figure 262 shows some of the simple methods that experienced workmen use in finishing the interiors of Masonite dies—sandpaper and scrapers. These die blocks can be made ready for use at one-tenth the time and cost necessary for finishing steel dies, and they are less than one-sixth the weight of steel.

Forming Dies in Use.—Figure 263 shows a half dozen different shapes of parts being formed at one time in a large hydraulic press provided with a soft-rubber platen. A sliding table is mounted on a frame in front of the press. The dies on the table can be loaded with

blanks and then moved over the press anvil and under the platen. The table can be moved out after the operation and the finished parts removed from the dies. (See also Plate XX, page 427.)

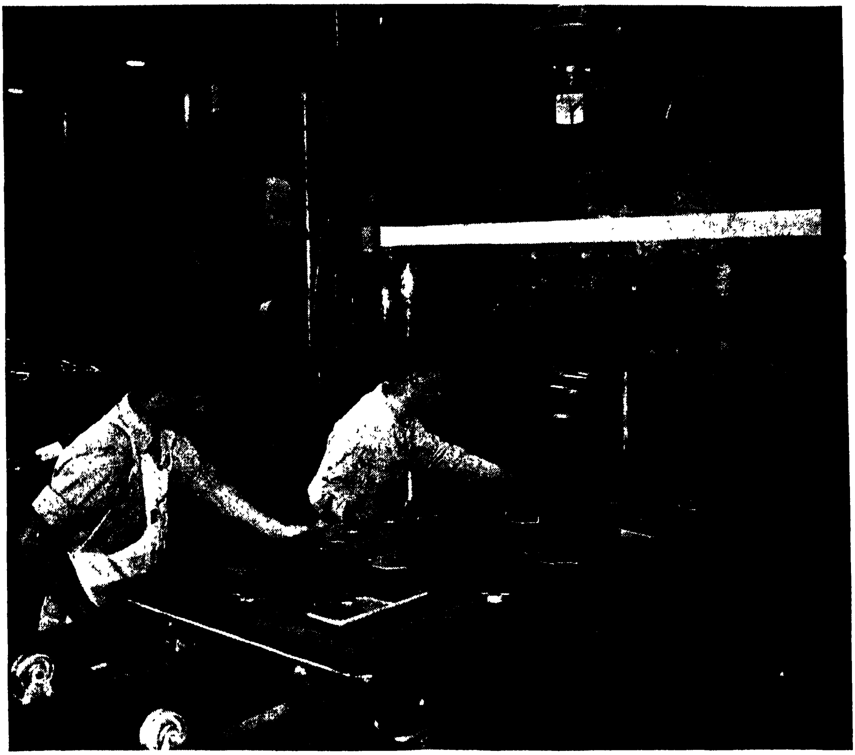


FIG. 263.—Seven dies covered with blanks and placed on a sliding table ready to be pushed under the press platen of a large hydraulic press. The platen contains a soft rubber pad which forms all the blanks in one downstroke. (*Courtesy of Masonite Corporation.*)

Drawing and Forming an Aircraft Bulkhead.—This operation involves too many difficulties to be done in a rubber platen forming die. The blank is of too heavy material and the shell too deep for rubber forming. The drawing punch, die, and a sample of the drawn piece are shown in Fig. 264. The tool members were machined from blocks of laminated sheets of Masonite, glued together. The drawing die is seen on the bench, and the blankholder pressure plate lies over it. This operation is done in a large hydraulic press.

Drawing Large Cylindrical Shells.—Figure 265 shows the operation of an inverted drawing die set up in a large hydraulic press. The die block itself is composed of the three laminated composition sheets seen (glued together) above the punch, suspended from the press

FIG. 264.—Drawing punch and die made of Masonite die stock and showing the sheet product which is a bulkhead stiffened with ribs, as produced by the Grumman Aircraft Engineering Corporation.

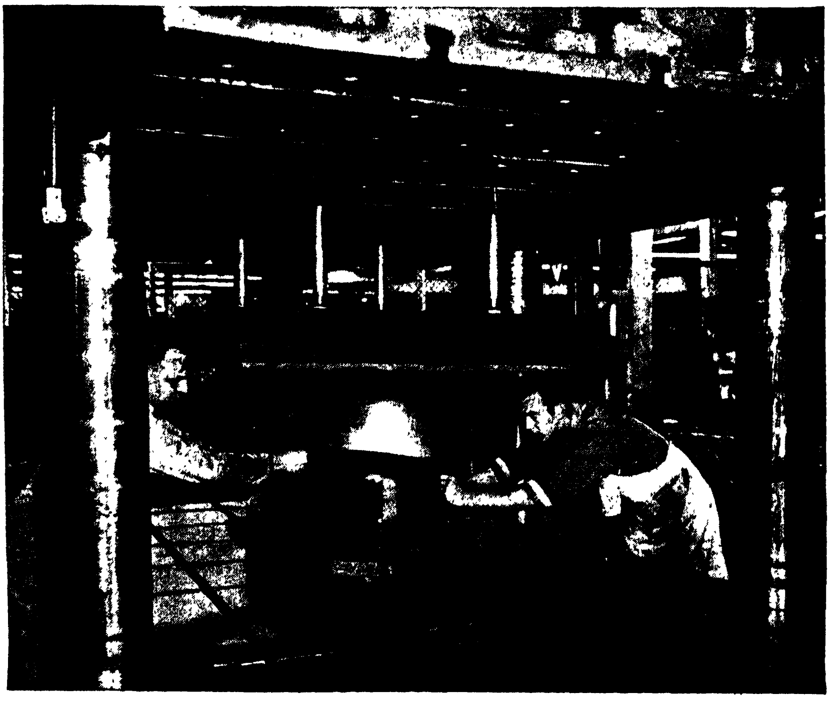


FIG. 265.—Deep-draw die made of Masonite die stock to produce landing-gear wheel pockets at Grumman Aircraft Engineering Corporation's plant.

platen by vertical rods that work against a cushion. The die block is "faced" with a steel wear plate, as shown.

Two press operators are seen removing a large finished shell from the punch. The work is a shell pocket used for airplane landing wheels. Such dies can also be made almost entirely of hardwoods, with the parts that take the wear lined with steel plates. Two dies of these types are illustrated and described in Chap. IX, Figs. 179

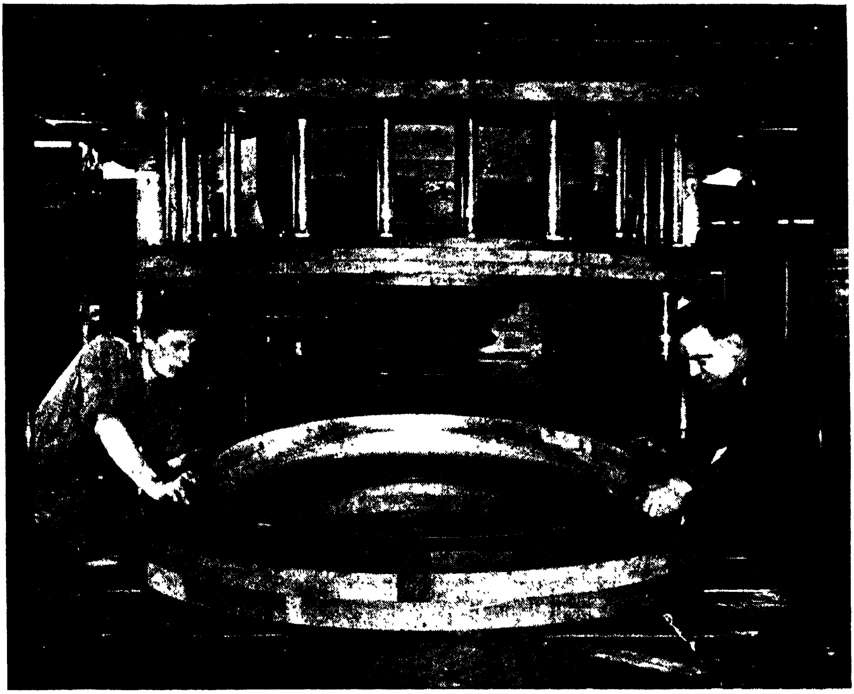


FIG. 266.—Large drawing die for producing a cowling ring, which is finally mounted around the front of airplane motors. The die, blankholder, and parts of the punch are composed of built-up laminated plates of Masonite die stock which are glued together. (View taken in Grumman Aircraft Engineering Corporation's plant.)

to 181. However, wood may absorb moisture and thus distort the active members of the die.

Figure 266 shows the operation of a conventional type of drawing die in which the punch is symmetrically positioned over the die. This tool draws a cowling ring for aircraft motors. The hole through the ring was cut in a previous operation. Around the punch is a laminated composition blankholder or pressure plate suspended from the press platen by vertical rods that work against a cushion. When the punch descends against a sheet metal blank placed over the die, the blankholder first contacts the sheet and holds it taut while the punch

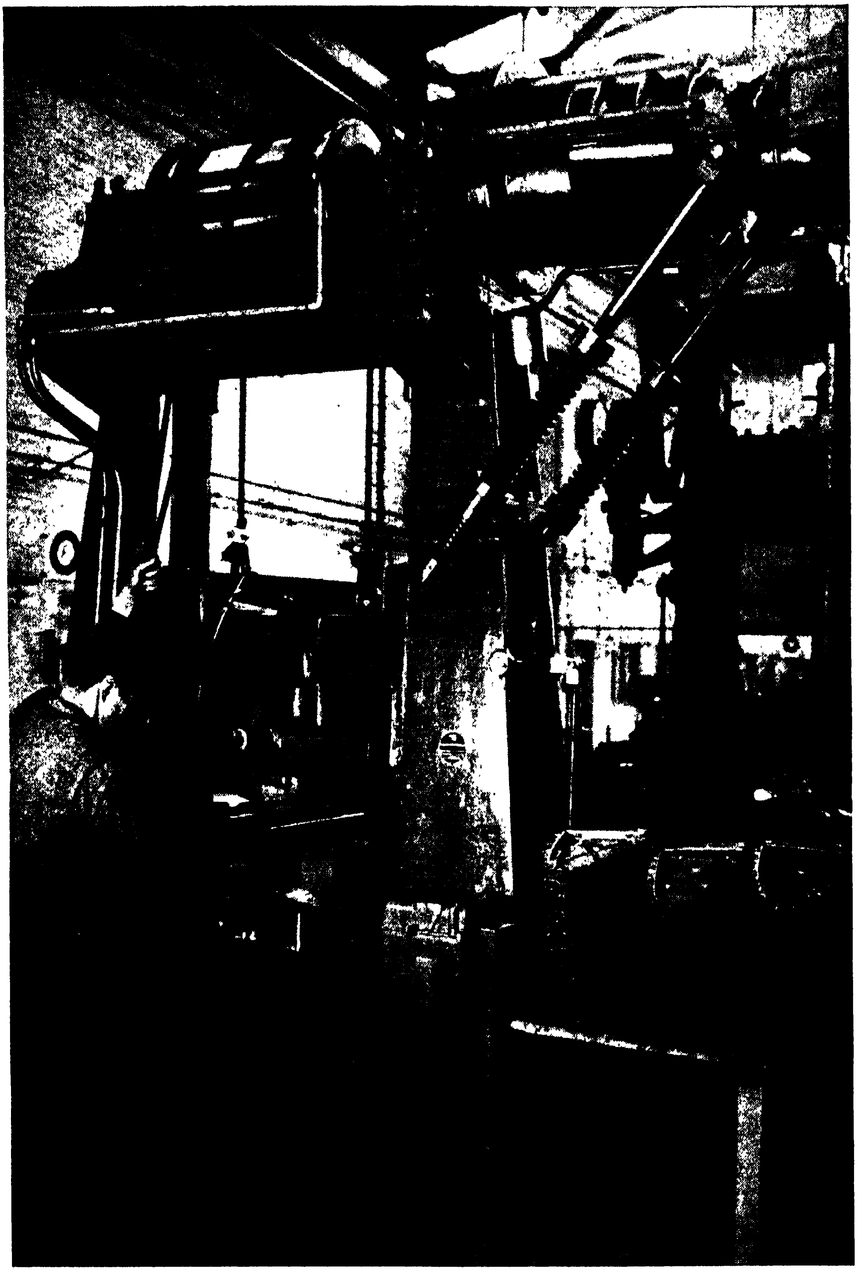


FIG. 267.—Nose sections of wing ribs are formed under rope-operated drop hammers using metal dies and rubber in the platen. Tightening the rope on the motor-operated drum raises the hammer ready for action. This view was taken in a German aircraft plant. (*Courtesy of American Machinist.*)

continues to descend, thus drawing the sheet from under the blank-holder and down into the die.

Aircraft Work in Germany.—Over one-third of Germany's Henschel Hs-126 observation plane is made of metal stampings. The tools, machines, and methods are very similar to those used in our country.

Ribs of sheet Duralumin for the wings are made in three sections to facilitate assembly in the wing jigs. Figure 267 shows the operation of a drop hammer of Henschel design used for forming the nose sections.

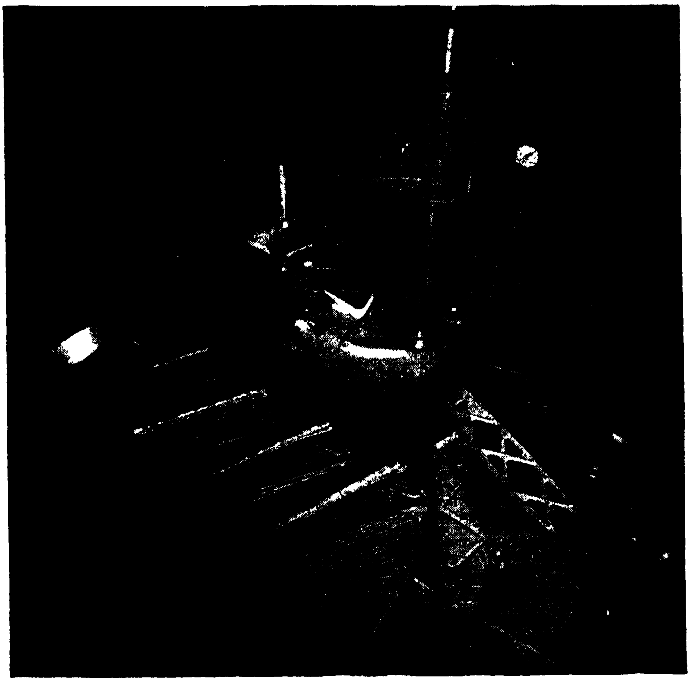


FIG. 268.—Hydraulic presses are used to form many structural members of the Henschel observation plane. The center rib sections are being made on this machine. (*Courtesy of American Machinist.*)

The metal die is secured to the table on the machine, and the rubber platen is attached to the hammer. An electric motor raises the hammer to its striking position.

The center and rear portions of the wing ribs are pressed out on a Muller (Henschel license) hydraulic press, Fig. 268. This machine is foot-operated and fast in action, and is used for a variety of presswork. As in the case of the drop hammer, the die is secured to the table, and the rubber platen is attached within the ram.

Approximately 120 dies of various shapes and sizes are used for pressing out parts for the wing ribs, the tail surfaces, and the control

surfaces of the airplane. Many of the dies used in the drop hammers and the hydraulic presses are made from plaster-cast models which, in turn, are obtained from full-size "mock-ups" of parts of the airplane. The frames for the cockpit enclosures and the side frames of the center section of the fuselage are typical parts made in this manner.

Plastalloy Punches for Aircraft Parts.—These punches are made of a plastic composition and are tough and elastic and possess great impact strength. When remolding these punches into new forms they are 100 per cent reclaimable and do not lose any of their physical properties. The use of Plastalloy punches introduces a new and more consistent method of forming sheet metal parts and a more rapid production of such parts in drop-hammer or hydraulic-press operations. The use of this material and processes, released to the trade as this book goes to press, is illustrated and described in the *American Machinist*, Feb. 4, 1943, issue, after extensive tests by the Tool Research Engineering Department of the Vega Aircraft Corporation, in collaboration with Leon Chapman, chief chemist, Plastalloy Company, Burbank, Calif.

Pressworking at Willow Run Bomber Plant.—This plant is the largest single manufacturing effort of its kind in the war. At the time this book was published, Willow Run had just started manufacturing on line production. However, the following information can be given.

For presswork, Ford engineers employed radical departures from the usual methods heretofore used by other manufacturers of airplanes, conventional blanking dies being extensively used in place of profiling or routing out of Duralumin blanks.

This technique greatly increased output and actually put the business on a mass-production basis. In forming and assembling aircraft parts, expensive dies were substituted in place of the Guerin process for shaping aircraft parts by the rubber platen methods. This was thought to be a further improvement in manufacturing methods.

It was possible to adopt this procedure because the major output, Consolidated Liberator four-motored bombing planes, were started off with a certain stability of design that approached a standard product. With assembly-line operations also stabilized, no changes will be made in tools, special machines, or methods, except when a low-cost change will increase the output.

Improvising Cheap Dies.—Low-cost dies are often "invented" to save time and expense. This idea is profitable if tools can be devised as simple and effective as the forming die shown in Fig. 269. Here,

commercial round steel shafts are used for punches, and the dies are simply V openings. Because the shapes of drawn and formed parts always follow the contour of the punch, this interesting operation is possible. The work produced is corrugated sheets used for stiffening airplane wing structures. The wing skins are subsequently riveted in place over these sheet metal corrugated ribs.

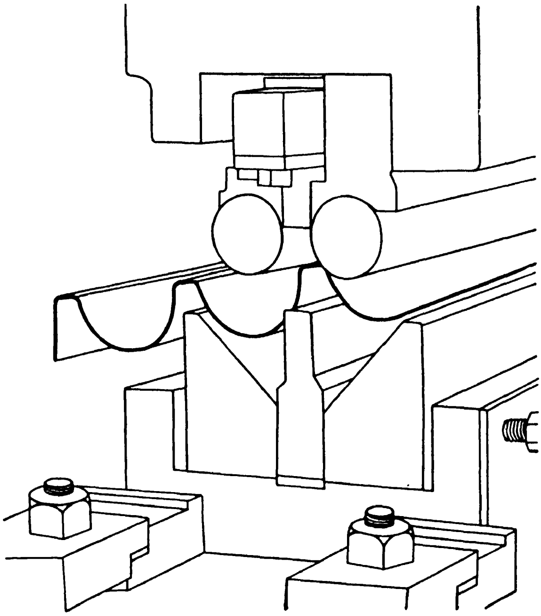


FIG. 269.—Illustrating the forming of corrugated stiffening sheets on which the smooth outer wing surfaces are riveted on planes made at the Lockheed Aircraft Corporation's plant, Burbank, Calif.

Forming High-strength Metal Alloys.—Stainless steels and many aluminum alloys present forming problems taxing the most modern types of stamping equipment. Many forms cannot be drawn without great difficulty, while others must be shaped without drawing the metal, because no reduction of section is permitted. However, it now seems that most of these difficulties have been eliminated by the introduction of the so-called "Cecostamp" equipment.

This method provides a means for handling these "hard-to-form metals" in fewer operations and with greater "true-to-die accuracy." It permits the operator to control the metal flow at will, when stamping, and thus enables him to produce shapes without drawing the metal and thus reducing its sectional areas.

Forming Thin Hot Work.—This operation requires high speed. Unless the forming can be done quickly, the material "chills" in

the dies, and must either be reheated or worked partially cold. The results are poor-quality work, short die life, and excessive wear on the mechanical equipment. Additional expense and loss of time accrues if the work must be reheated.

Controlled impact forging permits the operator to adjust the stamping time for the required rapidity and the power of successive blows necessary to form the metal before it has cooled beyond a good workable condition. Ideally suited for producing thin, hot, impact forging, this method provides a low-cost and a high-production means of fabricating this type of work.

Embossing.—Embossing and shallow forming in sharp relief are sometimes performed by pressure or squeeze. This is a phase of metalworking that presents many difficult problems, because the metal must be "upset" and drawn at the same time into the forms of the dies. This requires tremendous pressure and specially hardened tool-steel dies, and both are exceedingly costly.

The Cecostamp presents a different method of embossing, one that requires very inexpensive dies and no costly press equipment. Embossing is easily accomplished by controlled successive impact blows. This operation "flows" the metal into the dies without drawing it and without danger of tears or ruptures. (See Figs. 277 and 278.) Fast impact blows, adjusted to the correct pressure and speed by the operator, quickly give the metal a permanent and accurate "set." (See Fig. 276.)

Short-run Work.—Formerly, when a quantity of pieces to be formed did not justify the cost of expensive steel or cast-iron dies, forming was done manually by hammering and conforming the size to patterns. Today, short-run stampings can be inexpensively formed with the Cecostamp, which uses dies cast from lead and zinc in simple plaster molds. Occasionally, dies of hardwood, aluminum, and magnesium are used. These dies require no machining and, when no longer wanted, can be remelted with almost 100 per cent salvage of material. Figures 270 to 279 inclusive show detailed views of 10 cases in which aircraft parts are being fabricated by the processes just described. These pictures were taken in both American and British aircraft plants.

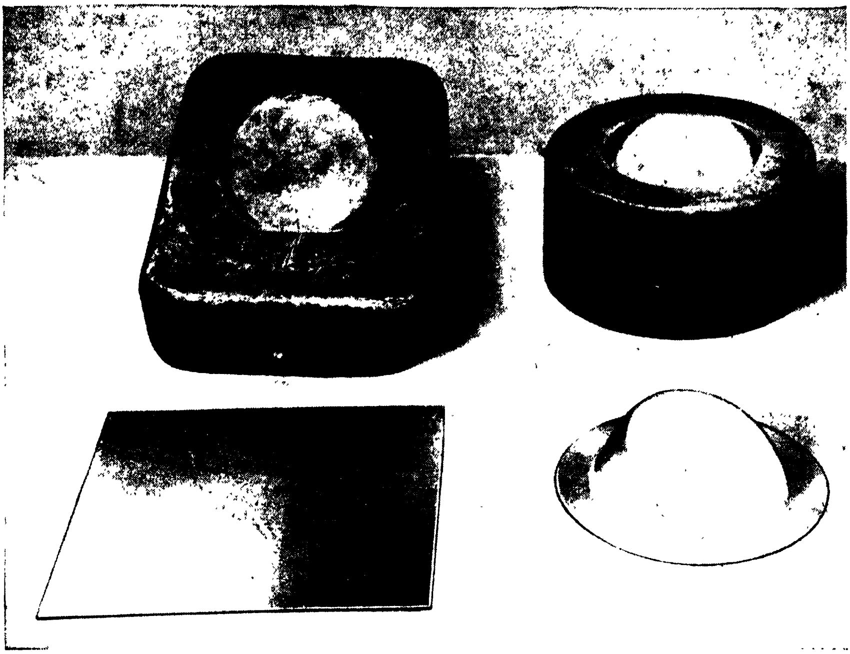


FIG. 270.—A punch, die, blank, and the finished product, which has been drawn in a cast lead-and-zinc-alloy punch and die.
(*Figures 270 to 279 are all courtesy of Chambersburg Engineering Company.*)

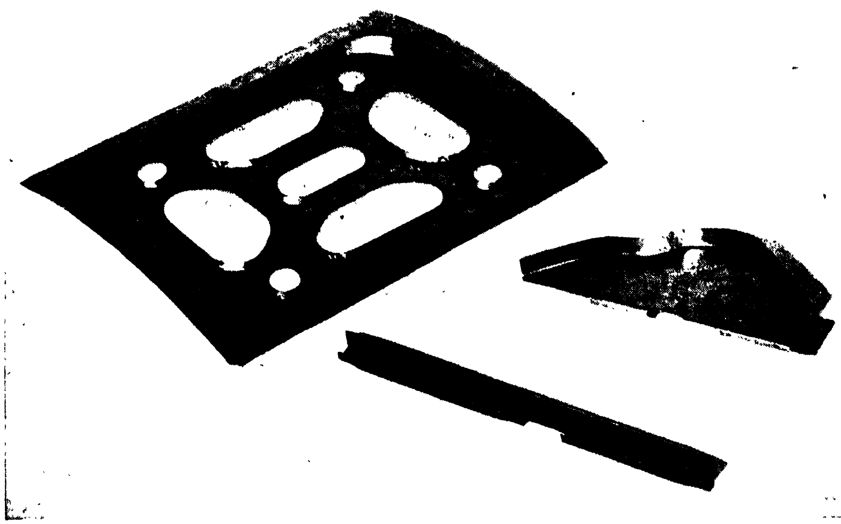


FIG. 271.—Radio panel and gussets made of Alcoa aluminum alloy S-014 (0.064 in. gage), showing difficult shallow drawing. These parts were stamped without using soft-rubber draw rings, but they require a limited amount of hand peening. The openings through the panel were punched out before the blank was formed.

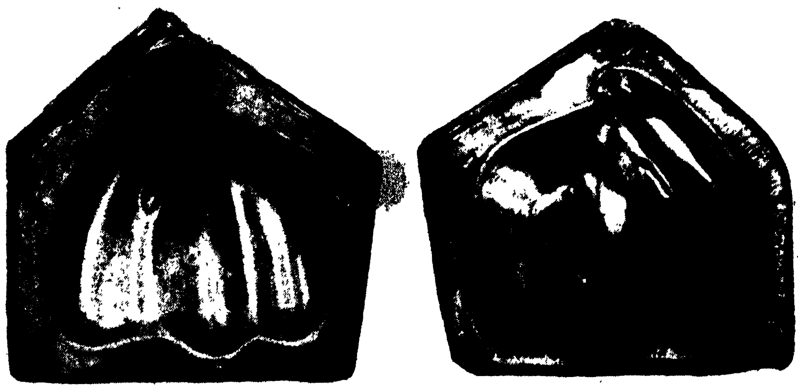


FIG. 272.—Duralumin parts for aircraft components, formed between lead punches and zinc dies.

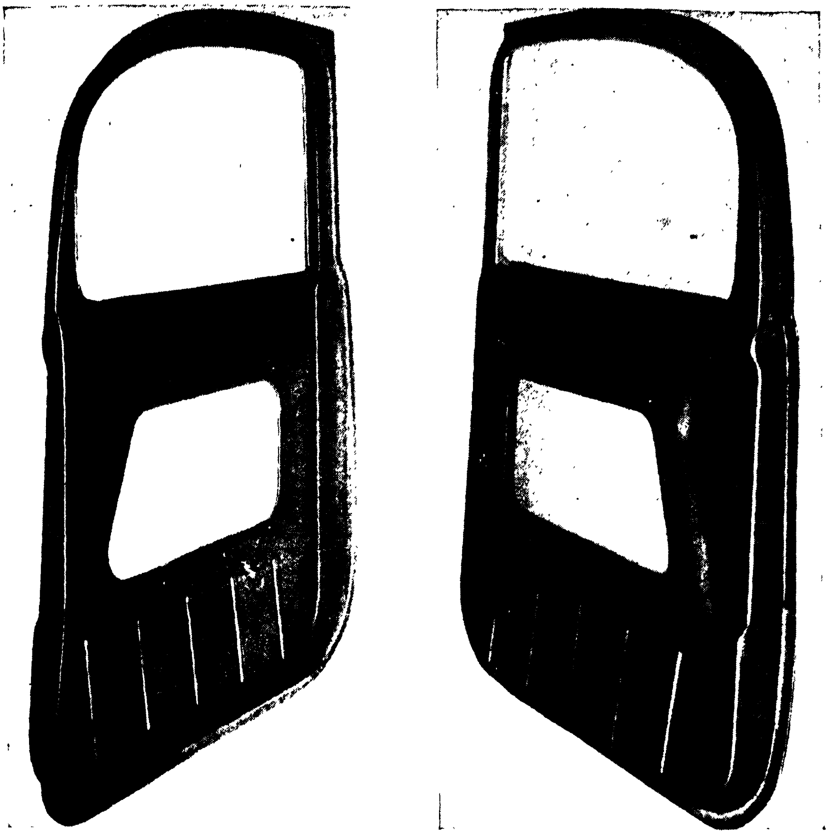


Fig. 273.—Airplane door, approximately 34 in. long and 22 in. wide. Made of aluminum alloy on a 36- by 48-in. Cecostamp.

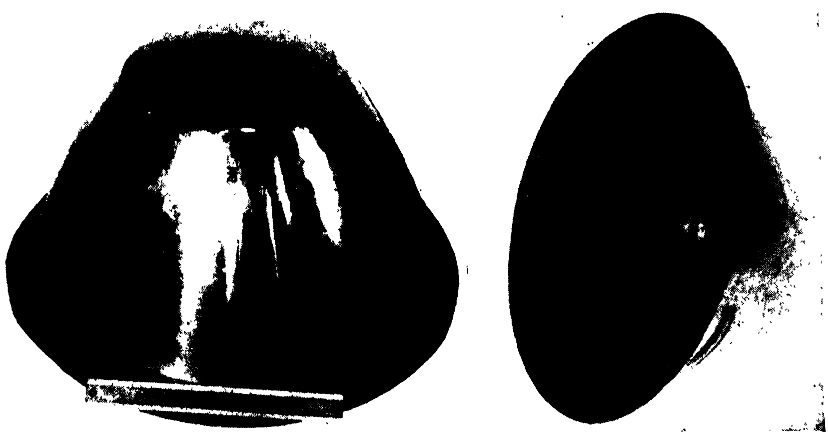


Fig. 274.—Airplane nose, or "propeller spinner," made from Stainless steel on a 48- by 66-in. Cecostamp. Soft-rubber rings were used extensively for producing this deep-drawn job.

FIG. 275.—A close-up view showing intricate dies of cast lead and zinc mounted in a press ready to use. The punches and dies are cast in plaster molds and need little or no finishing.

FIG. 276.—A close-up view taken in the Glenn L. Martin aircraft plant which shows the details of work in progress. The operator has perfect control of the press strokes and pressures by means of the hand lever shown.

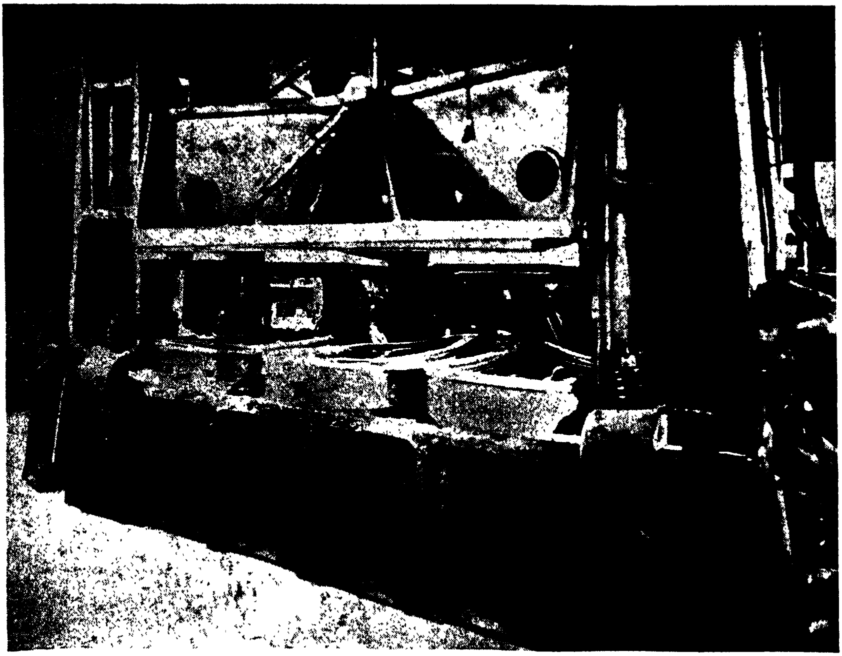


FIG. 277.—View taken in England of a drawing die operation in the Hawker Aircraft Plant, Ltd. Under the flanges and around the shell bodies being drawn in three dies on the press bed are thin plywood frames that surround the work and facilitate deep drawing of the shells, as explained in the next figure.

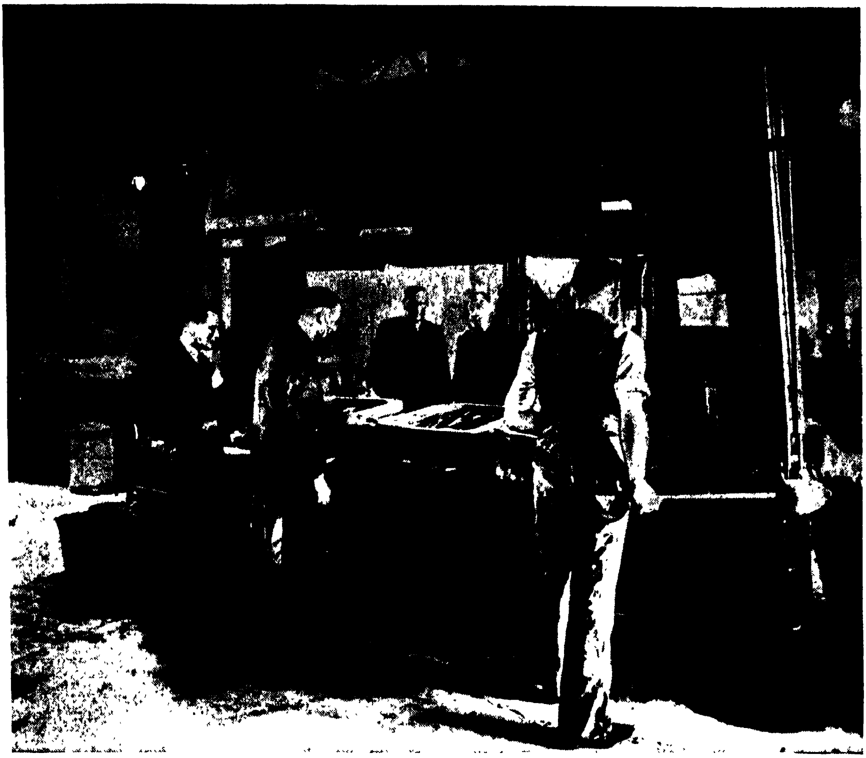


FIG. 278.—One of the thin plywood frames is removed after each descent of the punch, which permits the work to be drawn down into the dies gradually. The final, or the "setting," blow is delivered on a metal plate which is attached within the bottom of the die and under the work.

FIG. 279.—A battery of six Cecostamp "giants," shown in one of the several press departments of the Glenn L. Martin Company's plant. Here are produced hundreds of thousands of intricate stampings similar to those shown in the preceding photographs.

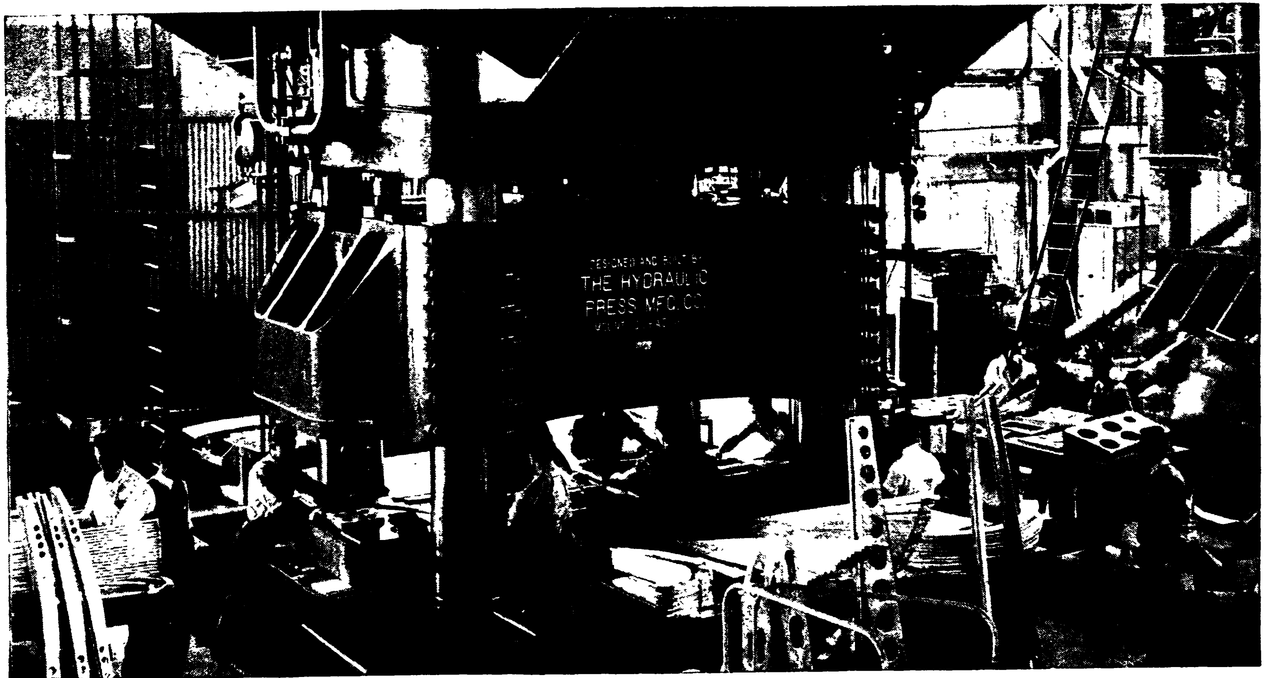


PLATE IV.—Production under pressure. A giant hydraulic press cuts and forms at great speed Duralumin parts for airplanes. This patented Guerin process—used in the Douglas Aircraft plant at Santa Monica, Calif.—turns out 37,000 parts a day on this 5,000-ton press and 15,500 parts a day on a smaller 2,000-ton press, a total of 52,500 parts every 24 hr., or 1,260,000 parts per month for an average potential production of four to five planes a day. The press ram carries a frame that contains a compressed-rubber face. When the ram descends, the rubber cuts and forms the blanks placed over metal forms shown on the bolster plate. Six operators place the blanks and remove the finished pieces. (*Acme photograph.*)

Plate V.—Guerin process set up for cutting and forming blanks, showing a hydraulic press ram equipped with the master rubber pad compressed within its container, which, in descent, cuts and forms great quantities of metal aircraft parts, as shown in Plates IV and VII. (*Courtesy of Douglas Aircraft Company.*)

PLATE VI.—Preparing to cut and form blanks by the Guerin process. A group of blanks are placed over their respective metal forms before the blanking and forming. (*Courtesy of Douglas Aircraft Company.*)

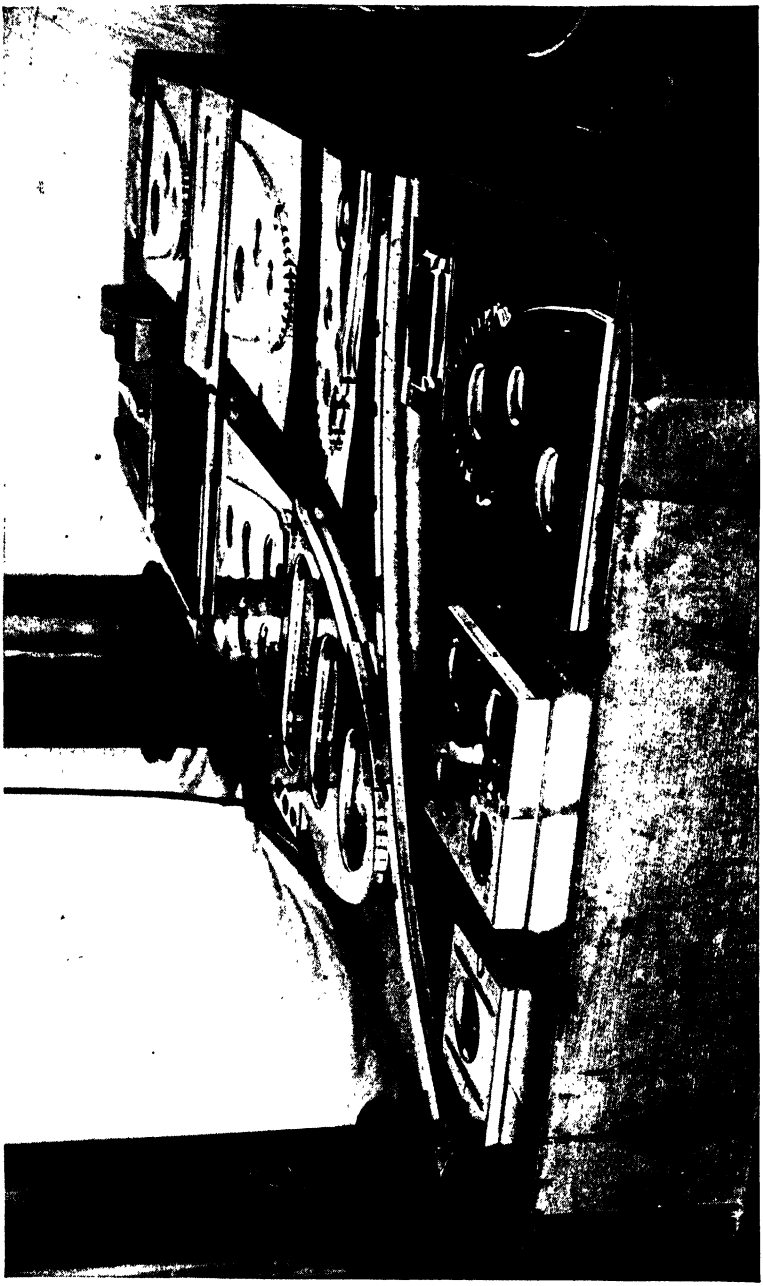


PLATE VII.—Blanks cut and formed by the Guerin process. The same group of blanks as shown in Plate VI, ready to be removed after the operations have been completed and the aircraft parts cut and formed. (*Courtesy of Douglas Aircraft Company.*)

CHAPTER XII

HYDROSTATIC DIES

Hydrostatic dies, commonly called "fluid dies," operate on the same general principle as hydraulic presses, namely, the pressure exerted by a confined liquid. The work produced in these dies is the result of pouring a liquid into the shell to be operated upon in the die, and then introducing a high pressure on the liquid until the operation is completed.

Pressure on the liquid may be produced by the force of a powerful pump, but preferably by the descent of a close-fitted punch into the mouth of the shell. The latter operation is done in an ordinary power press. Commercial cutting compound is the liquid used; water is avoided because it causes rust. However, for high outputs of large work, water may be used to avoid the expense of using compounds. Grease, oil, wax, or soft rubber may be substituted in place of fluid, depending, of course, upon the size, shape, and conditions of the work.

The successful design and operation of hydrostatic dies is an art in itself. Many "spun" parts can, instead, be hydrostatically expanded. Hydrostatic dies are probably the best known method for shaping artificial limbs from Duralumin and magnesium alloys, or of thin-gage metals which have low specific gravities. They are used for bending and twisting long tubular work, producing ornamental tubular designs, curling metal tubes, and expanding tapered horn connections for vocallions, pipe organs, and a large variety of wind musical instruments. One government arsenal has conducted a long series of experiments in using these dies in the fabrication of certain important parts of war equipment.

Horizontal Fluid Dies.—For long work, the dies must necessarily be used in a horizontal position, and a large press with a long stroke is necessary. The shell is filled with city water, and its mouth is "plugged" with wax. A horizontal punch is used, and side cams must be arranged in the die to operate the punch from the ram. In bending, twisting, and curling, the operation is performed by applying fluid pressure against the inner end of the shell bottom, and the work is forced around one or more bends, or turns, provided in the die.

When expanding and bending tubes and shells simultaneously, it becomes necessary to use differential pressures. A piston is provided

to push the shell forward in the die as it bends or expands, and at the same time sufficient pressure must be maintained inside the shell to prevent its collapsing while bending, or to expand it. If the piston pressure is too great, the shell will buckle or collapse; on the other hand, too great an internal pressure will cause the bottom of the shell to "blow out."

High Brass Best for Fluid Die Products.—In Fig. 280, at *C*, is shown the well-known "doorknob type" of shell, which has been expanded, drawn, and formed in a fluid die. It is produced from the brass shell shown at *E*, which is an ordinary cylindrical shell drawn in three die operations. The side wall thickness of *E*, is reduced 0.010 in.; this leaves a bottom slightly thicker than the sides. The material used is known to the trade as "sheet high brass," and its thickness is No. 14 Brown & Sharpe gage (0.064 in.). Its approximate chemical content is: copper, 66; zinc, 33.50; lead minimum, 0.30; iron minimum, 0.05; and all other impurities, a minimum of 0.10 per cent.

The temper of the metal is soft annealed, and in this case it has a Brinell hardness of 47 to 55, a tensile strength of 40,000 lb. per square inch, and an elongation in 2 in. of 42 per cent. This material, with the physical properties and temper given, is obviously ideal for fluid die operations.

Cupronickel is used for the jackets on bullets for army and navy small arms. There are 10 operations, which are all done on a dial-fed press, without annealing. After the last operation, the jacket can be crushed in a vise without showing a fracture. This feature alone makes it worth investigating as a substitute for parts that must have several annealings, and this test also indicates that cupronickel would be particularly useful for hydrostatic die work that is successively expanded from within.

Recent Discovery Promotes Workability of Metals.—The "electron microscope" developed in the RCA laboratories surpasses in magnifying power all the present types of lens microscopes by 50 to 100 times. Lens microscopes depend entirely upon the light reflected from an object for the enlargement of it in the lens, while this new device reveals objects too small to reflect light. This discovery is good news for those engaged in hydrostatic die work.

This instrument is able to expose the molecular structure in work materials, and to show practical reasons for their strengths, faults, or failures. The time seems to have arrived when samples of metals can be scientifically examined and the reasons shown for their critical faults, so that physical defects can be avoided. An exceedingly soft-annealed mild sheet steel is already in use which promises good results

in the production of both large and small products in hydrostatic dies.

Shell Formulas.—The mathematics involved in Fig. 280 is the formula for the blank diameter D for shell E.

$$D = \sqrt{d^2 + 4d(H + 0.057r)},$$

in which the medial line L of the shell walls determines its diameter. The lengths of lines L in both shells C and E are equal, and, of course, the shell wall volumes are also equal. The difference between the shell heights G and F represents the height that shell E loses after having produced the circular bulge around shell C.

No Thinning of Shell Walls.—The above conditions indicate that the operation of bulging shells in fluid dies does not seriously "thin" the walls. The supply of metal necessary for expanding the shell is drawn from the shell height, and for this reason the height recedes rapidly when the punch descends into the shell and forces the fluid it contains to draw the bulge.

Bulging without Reducing Shell Height.—In these operations the mouth of the shell is surrounded by a flange or rim which, during the punch descent, is held down on the surface of the die block by a pressure plate. This is a condition that does not permit the shell height to recede when bulging the shell wall. Thus the bulge is purely a stretching operation around which the shell walls become thinner. The limitations of these conditions are given by E. V. Crane in *Plastic Working of Metals*, as follows.

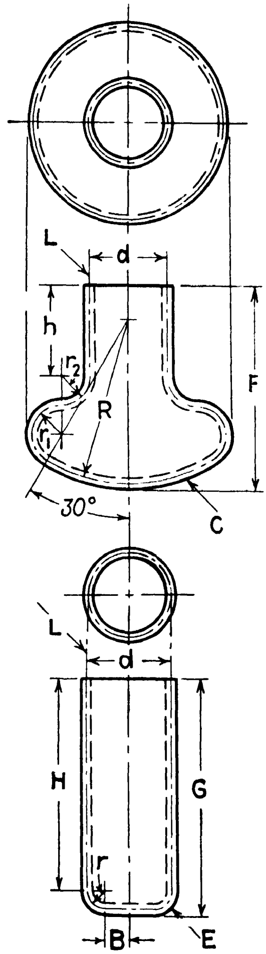


FIG. 280.—Shell C is expanded and drawn to shape from the original shell shown at E by the hydrostatic die illustrated in Fig. 281.

The limitation upon bulging, as in other operations, is the amount of cold-working the metal will stand before it fractures. An increase in circumference (or diameter) of about 30 per cent in one operation is the most that is ordinarily expected of the ductile metals in the annealed state. This includes low-carbon steel, alpha brass, copper, aluminum, and silver particularly. The

per cent elongation in 2 in., of the metal, is an index to its bulging limitations.* The portion of a drawn shell which has been severely cold-worked in drawing must be annealed, of course, for a severe bulge. An excessive bulge may be accomplished in two or three steps with intermediate annealings, even using the same die with different settings.

Embossing Artistic Work.—In this connection, artistic designs can be reproduced by embossing them on the shells. If the inside surfaces of the die, around the bulge, are engraved with characters, figures, or designs, the metal, while under the expansion pressure, will emboss each minute line, and the finished pieces will present a very satisfactory appearance. As with printer's type, the letters and figures must be engraved in reversed positions within the die, in order to read them from left to right on the finished work.

Die Blocks Must Be Rigidly Locked.—The reproduction of delicate designs in fluid dies also points to the fact that the split separation lines between the die blocks will also be embossed on the work. These lines are not always objectionable, but, if so, it will be necessary to remove them. It cannot be emphasized too strongly that in all hydrostatic dies, the die blocks must be rigidly locked together before the punch descends. The movable sections must be provided with suitable hinges, slides, wedges, or latches that are not only easy and rapid to operate, but will hold the blocks so tightly together that internal pressures up to 5,000 lb. per square inch will not spread the blocks enough to emboss the separation lines.

A Powerful Punch of Water.—The shell, filled with water, is held securely within the closed sections of a split die. When the press is operated, a close-fitted punch descends into the mouth of the shell. Water being incompressible and the walls of the die strong, one of two things must happen. Either the shell must be pushed down into the die the same distance the punch descends against the water, or the pressure "set up" must burst the shell. If the shell rests upon the bottom of the die, the water pressure set up by the punch descent must escape, and in following the path of least resistance it expands the shell into the interior shape of the die. If shell expansion were impossible in any direction, the effect would be almost the same as bringing the punch down on solid metal. Success depends largely upon the thickness of the metal used and its annealed condition. The metal thickness should not exceed 0.050 to 0.060 in., unless the material is very ductile.

* The physical properties, including percentages of elongation in 2 in., for commonly used metals are given by the author in "Pressworking of Metals," McGraw-Hill Book Company, Inc., New York.

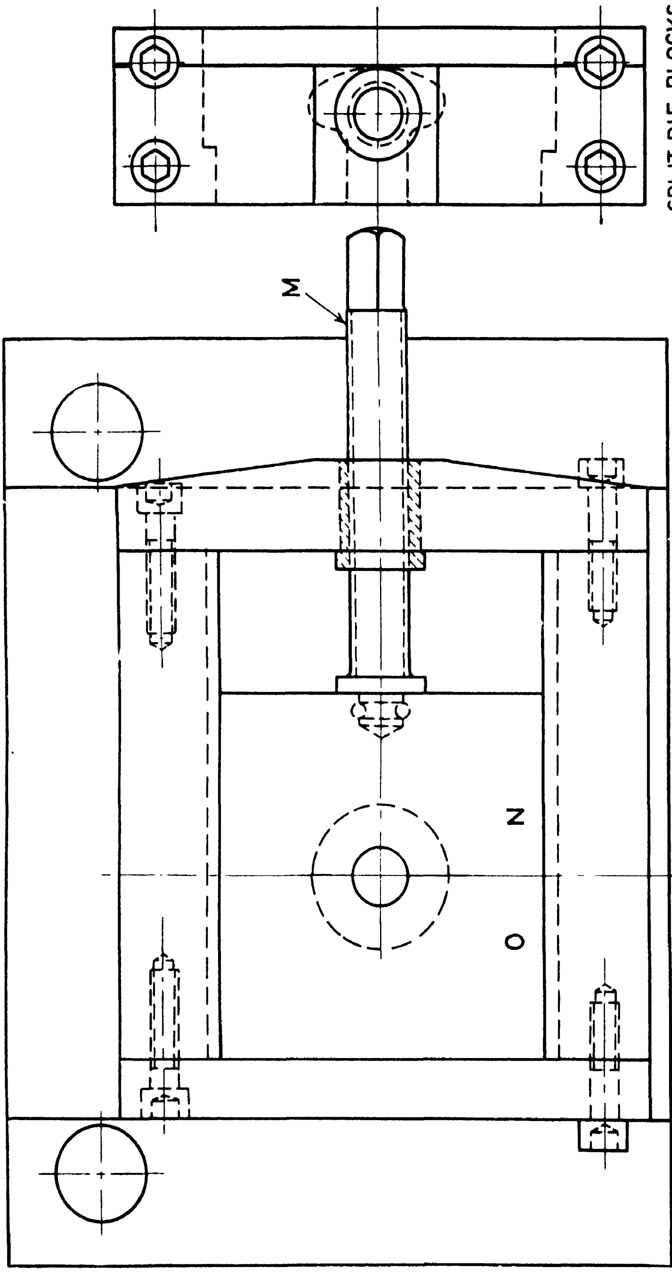
In simple bulging operations the bottom of the shell rests against the floor of the die and the top is enclosed in a neck the size of the original shell. When the punch descends into the neck of the shell, the fluid pressure expands the work in all unconfined directions. As the punch continues to descend, this expansion continues until the shell walls are solidly against the inner die at every point. There are instances, such as the elbows of certain musical instruments, where both bending and expanding are necessary, but the principle of operation is the same.

"Setting Up" the Die.—To ascertain just how far an operation can be carried, we must "burst" the bottoms out of a few shells, or "blow out" their sides. This is necessary only when making the first setup. After the punch-pressure depth has been determined, it is scribed on the side of the punch as a guide in future operations. Stop pins can then be inserted between the punch holder and the die shoe, so that the shut height of the die agrees with the scribed line on the punch. Of course, if the next lot of shells have different physical properties, or the annealing is not uniform, the same troubles will be encountered as when redrawing shells in ordinary drawing dies.

In work where a small mark on the bottom is permissible, a vent hole is provided through the bottom of the die, where the shell touches. Using a vent depends upon the thickness of the material used. The hole diameter should be $\frac{3}{16}$ of the shell diameter at the contact point of shell and die. Under excessive pressure, the bottom of the shell will blow out through the hole, which acts as a safety valve. Care must be taken that the vent hole points in a safe direction.

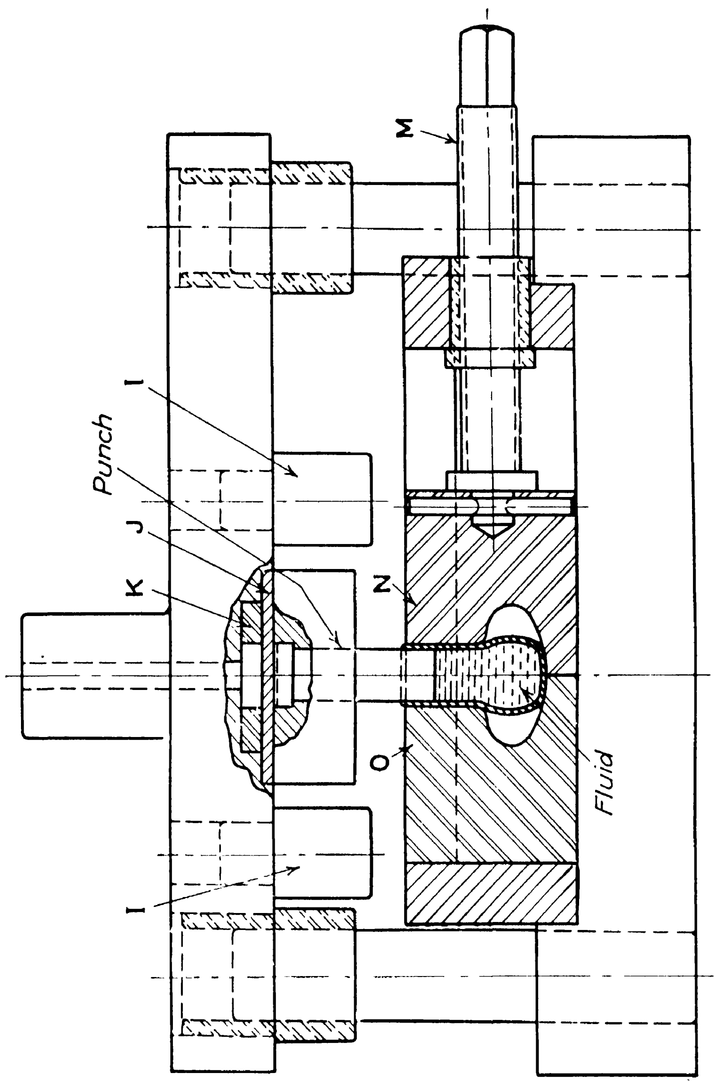
Design and Operation of Fluid Dies.—Whether the work is bending or bulging or both, the neck of a straight shell is necessarily drawn deeper into the die when the shell body expands. The neck of the die must be long enough to compensate for this recession of metal, plus from one-half to one diameter of the punch. The shell, likewise, must be of sufficient length to allow for this recession while the body is expanding. The recession is shown in Fig. 280 by the difference between *G* and *F*, which are the heights of shells *E* and *C*. The punch must fit within the neck of the shell closely and enter about half its diameter before expansion begins.

A design for a fluid die of the type just described is seen in Fig. 281. The shell at *E*, Fig. 280, has been inserted between the closed halves of the die and is filled with the fluid to be used; the punch has entered the shell, and expansion has just started toward completing the shell shown at *C* in Fig. 280. Two "bumper pins" *I* stop the punch descent when the work is completed. At *J*, a cold-rolled steel plate is inserted



SPLIT DIE BLOCKS ASSEMBLY

PLAN OF DIE



FRONT ELEVATION

FIG. 281.—A hydrostatic die showing a heavy locking screw M applied against the movable die block N. The screw is operated with a milling vise wrench and prevents blocks N and O from spreading apart under high fluid pressure, which would mark the parting line on the work. The screw with block N is backed away when removing the completed work from the die.

over the punch. This plate acts as a safeguard by preventing injury to the press. If the pressure on the punch exceeds, say, 16 tons, the head of the punch shears through plate J into die K. If the press capacity is 24 tons, a 16-ton load is safe. The formula for determining the shearing capacity of the punch in tons $= 78 \times D \times T$, in which D is the head diameter of the punch and T the thickness of plate J, using all dimensions in inches. The formula given is for shearing through a mild-steel plate.

Expanding Shells with Soft Rubber.—Grease or wax is sometimes used instead of fluid for expanding certain types of small work. In

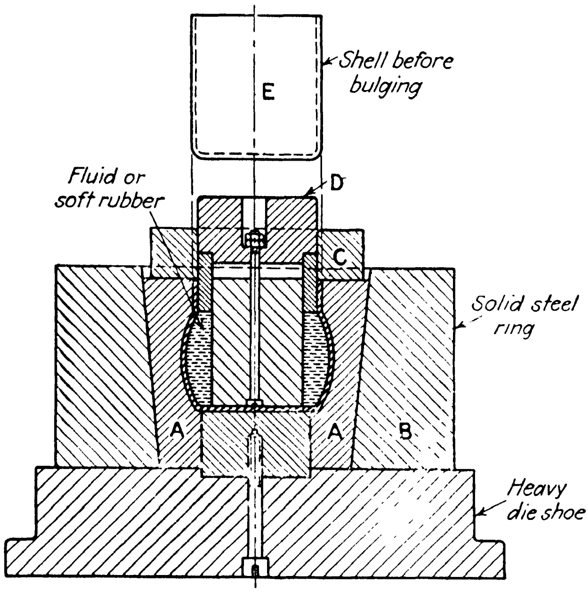


FIG. 282.—Four tapered die segments A, of circular contour, open outward when raised to release a shell that has been bulged by fluid or soft rubber.

other cases, soft rubber is used. An illustration of an expanding die in which either a fluid or soft rubber can be used is given in Fig. 282. This die is used in a double-action press. The die itself is composed of four tapered segments A, which can be closed together within the solid steel ring B. The blankholder ram is attached to ring C and descends first, and this action closes and holds the die segments shut. The expanding punch D follows, compresses the fluid o. rubber, and completes the bulging operation. When soft rubber is used, it is of tubular form and is stretched by forcing it on to the punch. Above the die is a sketch of the drawn shell E as it appears before expanding.

Soft-rubber Punches.—Punches made entirely of soft rubber can be used in conjunction with segmental dies for many types of small bulging operations. In all such cases, the die must be designed to surround the work completely. When the press ram descends and compresses the rubber punch inside the shell, the work is forced to expand and to fit within the contour of the die segments. Rubber expanding dies are used mostly in the production of small work and for only a few hundred parts per run. The rubber punch must be replaced with new "live rubber" after bulging several hundred pieces of work. When soft rubber or wax can be used for bulging shells instead of

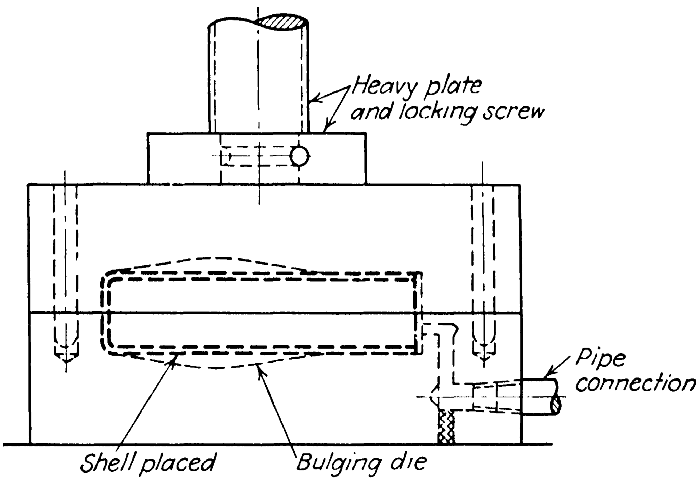


FIG. 283.—A horizontal die and its bulging blocks which can be used on a bench in connection with a fluid-pressure pipe.

liquids, all the muss and undesirable conditions encountered when using oil or liquids can be avoided.

Horizontal Bulging Die.—The design of a pair of horizontal bulging blocks is indicated in Fig. 283. This setup is used on a bench, and liquid is introduced through a pipe connection from a tank fed by a pressure pump. Pressures up to 1,200 lb. per square inch are thus obtained. The blocks can be separated by backing up the screw shown over the die. The finished piece is then removed, another shell placed, and the screw advanced and tightened over the blocks, ready to bulge the next shell.

CHAPTER XIII

FORGING,* COINING, SWAGING, EXTRUDING

Introduction.—Operations commonly used in the forging industry cover a wide variety of metalworking operations. Engineering experiments together with production experiences have influenced forging design as well as forging sequence. Hammer makers and steel manufacturers have also contributed liberally to the science of making better forgings.

Mass production requires that forgings be consistent in size and uniformity, with a minimum of machining stock, easy to machine, and to meet specified physical conditions and wearing qualities. Aircraft forgings must be as nearly perfect as it is possible to make them because of the severe performance to which they are subjected. They must be of very light weight, but must conform to the highest safety factor.

Starting with a given part to manufacture and a sheet listing the operation sequence, the design of the forging die centers around the number of pieces to be made, the kind of steel from which the forging is to be made, and the design of the forging itself.

The efficiency of a forging die is never determined by the correctness of the finished impression; the important point is how well the die will perform in production, which condition depends on the preliminary operations which prepare the piece for the finish blows.

Forging Steel Used.—Common forging materials are usually of the S.A.E. 1020 type steels, which lend themselves to easy metal flow within a wide range of forge heating temperatures. With the increase of carbon content, the plasticity of the heated metal decreases; the resulting flow resistance tends to slow down production and to decrease die life. The close range of forging temperatures and flow resistance of alloy steels also give added forging difficulties.

Forging Die Designs.—Engineering departments must realize the importance of complete, easily read, and accurate drawings, so that no questions may arise that cause loss of time and mistakes after the drawing is issued. The success or failure of the die will depend upon

* John Mueller, Assistant Superintendent, Cleveland Hardware & Forging Company, in *Heat Treating and Forging.*

sound principles based on past experiences and on engineering ingenuity in die design and material selection. The basic principle of die design is to cause the heated metal to flow into the succeeding impressions by reducing, gathering, shaping, and bending the blank for the final finish impression with the least amount of time, number of hammer blows, and flash waste.

Economic die design depends largely upon the production required from the dies; forging steels; hot metal contact; heating of stock; scale abrasion; forging tolerances; forging design; and operation sequence. If the die must be removed from the hammer every few hundred pieces and polished because of hard steels, overheated dies, and metal contact of a complicated forging design, the cost will be high.

The design of the piece to be forged determines the size of the stock and the "gathering" and reducing operations. Rolled stock is used for simple forgings. For forgings with sectional variations beyond economical limits, however, the gathering operations are performed in separate dies. Preforging, upsetting, and drawing-out operations are customary to prepare the stock for finish operations with a minimum of flash and working time. For long runs of simple forgings, the gathering operations are sometimes done at the steel mills, as in rolling round bars. Rolling consists of a number of upsetting and drawing operations performed consecutively over the bar length, which are later sheared to proper lengths for finish forging.

There is no exact formula for determining the breakdown, or roller and edger. Sectional areas are determined at intervals for the length of the piece, cross-sectional areas are figured, and the breakdown is made accordingly, with a percentage allowed for flash and a safety factor. Sections not readily figured are obtained by the use of a planimeter, which is traced around the outline of the section.

A Typical Forged Piece.—Figure 284 shows a forging called a "radius rod," with preliminary operations in sequence, bar blank, edger, rougher, finisher in double forging with flash, trimmed forging, upset forging with flash, and trimmed upset forging.

The flash on the forging dies permits an outlet for superfluous metal and serves as a pressure vent in "flowing" the metal into the die cavity. The usual procedure is to make the flash smaller where the metal is to be confined and increased where the material is to be "flowed" away from the impression. A "riffle," or trench, is often provided in the flash section where the metal is to be "trapped" to prevent excessive overflow, and this helps to fill the die cavity.

Draft is the taper on the side walls of the forging. To avoid excessive stock for machining, the draft should be held to a minimum

but should be sufficient to permit easy withdrawal of the work from the forging die. There may be different angles for the draft in the same die, depending on the position of the parting line.

It is important that the depth of the die halves should not exceed two-thirds of the smallest width of the impression. It should also

FIG. 284.—A sequence of forging operations for making a radius-rod foot. The example selected here shows a fairly difficult part forged double. The part has ribs and thin sections and an angle offset which requires a lock in the dies. A radius-rod foot is a right- and left-hand forging on which a length of tube is welded in a hole at the large ends. The completed part is used for brace rods on trucks. Two rods are used that form a "wishbone" shape, when assembled, for bracing the chassis against the rear axle.

be remembered that thin weak protrusions will not stand up well under heat and metal flow, because the protruded sections will soon soften and "wash out." Recesses should be large enough to ensure that the metal will flow into and out of the shoulder and rib impressions symmetrically.

Physical properties in the transverse direction of a forging are inferior to those in longitudinal directions. Rolled bar steels have a grain flow running lengthwise which will be retained if forged length-

wise. The shape and surplus material of a forging should be such that the fiber grain takes a minimum cut in machining.

The edger is the most widely used operation that governs forging metal flow. The metal is confined in the oval contour on the top and bottom of the forging die ends, but the sides can flow without resistance. Repeated blows of the hammer while rotating the piece after each blow result in an increase or upsetting of the bar over its original size. The ball and rolling edger, as used, confines the metal partly on all sides, rounding and shaping the bar while it is being formed to the desired shape and length in the die cavity.

The function of the fuller is the opposite to that of the edger. It is used for reducing the cross section of the bar and to flow the metal away from the center. The edger and fuller are used in combination for preliminary forging operations. Drawing is a reducing operation, as in "fullering," which differs only because the stock is reduced at one end only. The bender, as the name implies, bends the breakdown in relation to the finished impression.

Die Sinking.—Die sinking begins with the block planed and shanked, and with the necessary templates and prints on hand. Die faces are coppered and the layout is made. This is followed by the milling of impressions, namely, edger, roller, bender, rougher, finisher, gutter flash, gate, etc. After sinking, the die is moved to the die-sinker's bench for finish work, such as scraping, grinding, and polishing. Experimental "leads" are taken from time to time, and the final lead is submitted to inspection for check and approval. The lead is obtained by clamping the two die blocks together and pouring melted lead into the die cavity.

Simple forgings have the parting lines in the center, but when the parting line must change from one level to another, because of the forging shape, a "lock" in the die is created, which means that die faces that carry the impressions are at different heights. Locks are machined on the blocks before the impressions are sunk.

Whenever possible, the finish impression should be positioned in the center of the die, in order to place the heaviest work strains under the center of the ram, thus avoiding side thrust. It is important, as mentioned before, that the rougher have fillets as large as possible to assist metal flow. Projecting corners or edges should be well rounded to avoid checks; the radii on corners of forgings should be as large as possible. Regular shrinkage allowance for hot metal expansion in heating and shrinking when cooling is $\frac{3}{16}$ in. per foot, except where shrinkage allowance is for special conditions, such as high

or thin sections, which may require a special shrinkage allowance in places where normal shrinkage is restricted.

Die inserts are extensively used in many classes of work. The insert is placed in a holder or larger die of somewhat softer but tougher steel than the insert. Inserts are used for small forgings, additions to dies where a special type of steel is required, for added die life, and where other conditions may justify.

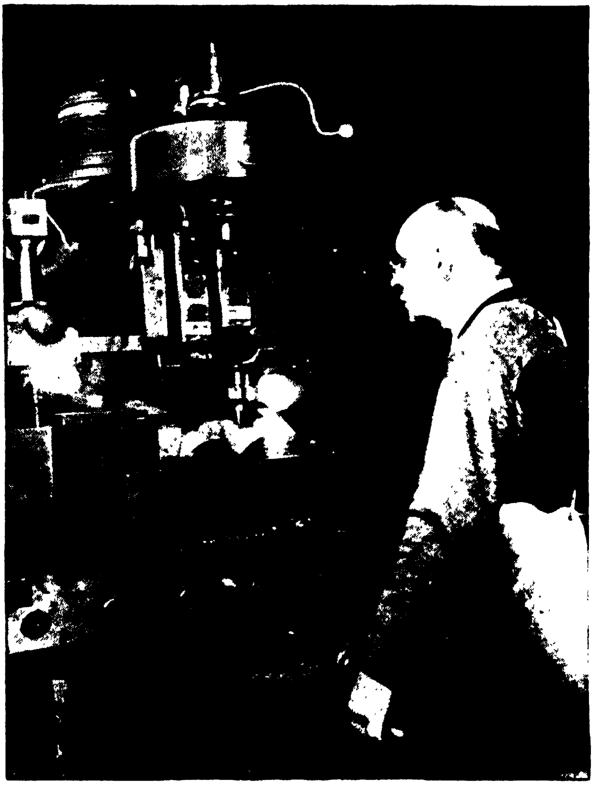


FIG. 285.—This toolmaker is sinking a die for making the radius-rod foot. The equipment is a die-sinking machine that has a duplicating attachment.

Each die sinker spends the greater portion of his time in planning, laying out, setting up, milling radii, arcs, and angles, and there is considerable time spent in duplicating. Where large runs justify a number of duplicate dies and where duplicating die-sinking machines are available, much time can be saved.

The usual procedure in sinking a die on the duplicating machine, and the proper setup of the master pattern and the die block, is to start with the largest cutter, and remove as much metal as possible, following with the next smaller cutter, using the heaviest feed possible,

and rough out to a depth of $\frac{1}{32}$ in. from the bottom, which is subsequently removed by the finishing cut. Figure 285 shows a die-sinking machine with a duplicating attachment.

Two types of duplicating machines are in use, namely, the electrically and the hydraulically actuated. The tracer point "feels its way" around a master pattern and guides the cutter into an exact reproduction of the master pattern on the die block. After machining, the die is hand-finished by a skilled worker.

Selection of Die Blocks.—The choice of the best die steels for forging dies and for a great variety of conditions is a problem in itself. No definite formula or rule can be given which will cover all conditions. Factors that govern the selection of die steel and its hardness are the forging shape and forging steel and production requirement. The primary limitation to the rate of output is the endurance of the die steels used in forging dies to withstand the severe hammer shocks placed upon them. Although the ability to determine the proper die steels comes largely from experience, additional information can be obtained from the steel manufacturer.

The most commonly used steels for die blocks are the chromium-nickel-molybdenum types, heat-treated to a hardness of from 40 to 60 Scleroscope in four ranges according to requirement. Sinking of impressions is completed in the hardened condition, thereby eliminating warpage and cracking. However, if dies do not stand up because of severe working conditions, annealed die blocks hardened after sinking are resorted to. When used as inserts, the sections must be kept in mind and hardened to secure greater toughness. The hardening limits must not exceed the breaking point.

The die blocks must be of a size that will withstand the hammer shock and must be large enough for the roller, edger, bender, rougher, finisher, and cut-off. Space must be provided for the flash and gutter and for enough section between the dies to prevent pounding together. A good rule is to use 35 sq. in. of striking surface per 1,000 lb. of ram pressure.

Heat is the greatest enemy of die life, especially where projections are surrounded by hot metal and where the time of metal contact is great. Scale abrasion is also detrimental to die life and should be provided for in the selection of die steel. The best way to prevent scale abrasion is careful heating of steel, scale removal, good die lubricant, and a die design that favors an easy flow of the metal.

Forging Production.—The ideal for hammer production would be the continuous-flow production principle, but this would be impossible in a plant producing a variety of forgings. Production time on any

job is a question of setup time, work-handling time, machine-handling time, and the actual forging time. Since the purpose of the job is the shaping of metal, we must place more importance on this subject. However, the completion of a given number of pieces in the least time is the object. Setup time can be reduced by using a permanent setup, standard layouts, die interchangeability, dies keyed or doweled when applied to presses or other machines working in conjunction with the hammer setup and thereby assuring correct lineup. Figure 286 shows a hammer in production, forging a part shown in Fig. 284.

FIG. 286.—Forging a radius-rod foot.

Setup must be arranged to comply with operation sequence to obtain a high degree of efficiency. Equipment suitable for handling dies to and from machines, and methods of handling material, must be adapted to the problems involved. Materials handling is closely related to plant layout since both share the common purpose of simplifying the transportation of work through the plant. Containers mounted on skids, handled by an overhead traveling crane, and with gas and electric trucks for surface transportation, is the usual procedure. Aisles must be of adequate width and well maintained.

Maintaining Dies.—No plant can obtain maximum continuity of production without a properly organized and equipped maintenance department, based on preventive rather than remedial measures. By means of various techniques, it is possible to save or salvage, recon-

dition, and return to service machines and dies or tools which would otherwise be scrapped. Welding is an essential part in the maintenance of forging equipment, dies, and trimmers, as well as in building dies, jigs, and fixtures. It is essential that regular inspection be made of all shop equipment and that spare parts be carried in stock. Except for emergency repairs, the maintenance department should schedule its work so as not to interfere with regular production hours. A delayed repair is reflected not only in decreased production and poor work, but also in breakage of parts and machines as well as danger to the safety of operators.

Heat Control.—The ability to control the temperature to close limits is largely a matter of selection and application of proper equipment and training of "heaters." Whenever it is necessary to operate a furnace at an undesirably high temperature to maintain production, to the detriment of the steel and furnace, it is evident that the heating area of the furnace is too small. Forging quality is controlled by the care and thought put into the heating of the stock preparatory to forging.

Design of the heating furnace should provide for the proper heating of the metal in relation to the forging hammer. If production permits, a continuous type of furnace should be adopted to provide an automatically controlled heating unit and to facilitate uniform heating and forging production. Actual hammer blows are dependent on the efficiency of the heating medium selected.

Good furnace design provides for high production and long soaking heats in a nonoxidizing atmosphere. Forging heat temperatures for steels range from 1900°F. for 1.5 carbon to 2400°F. for 0.10 carbon content. Alloy steels require slower heating and therefore a larger furnace capacity. The approximate heating range for alloy steels is 2150°F. Parts should be uniformly heated and forged as soon as they reach proper temperature.

The important difference between the heating of high-nickel steels, carbon steels, or chromium steels is the greater susceptibility of the former to attack by sulphur during heating. Care should be taken to avoid the use of fuels containing sulphur. Oil is most generally used, and natural gas is practical from the sulphur standpoint.

Scale abrasion is detrimental to the life of the die, and if not removed will be pounded into the forging surface, resulting in scale pits which are unsightly and may cause machining difficulties. Scale is usually knocked off in the breakdown operations, the loose scale being blown away by an air blast or steam. Other means of scale removal are cross rolling to break the scale, wire brush, and water spray. Not

only is scale detrimental to die life, but it also increases time for heating.

Trimming.—In forging, a surplus of thin flash is produced around the contour of the parting line, which is removed in a trimming operation. The trimming of forgings is performed on crank presses, which are arranged in rows with proper work space and aisles between for handling forgings and flash. Trimmed parts fall on a conveyer belt and are carried into crane boxes; the trimmed-off flash is thrown into

Fig. 287.—Hot-trimming the radius-rod foot.

flash containers. Another method of forging and flash handling is a conveyer belt beneath a row of presses which carries the forgings beyond the presses, where they may be sorted off the belt into containers. A belt conveyer running in the opposite direction at the side of a row of presses carries the flash to suitable containers. The flash from presses which is hot-trimmed at the hammer is accumulated in suitable containers and hoisted by electric lift trucks to the loading platform, where it is dumped into gondola cars. Another method is to bale the flash in order to conserve car space and facilitate handling.

Baling also facilitates remelting the flash at the mills. If unbaled flash is introduced into a furnace it will be instantly consumed by the heat and lost as scrap.

Trimming dies are classified as "hot" and "cold operations." Cold-trimming is suitable for light forgings, but it is advisable to hot-trim heavier parts. A normalizing or annealing operation usually precedes cold-trimming of hard steels.

Trimming dies may be as expensive as forging dies and must be carefully designed. The drawing should clearly specify when the trim must be closely sheared off the forged body, as no special grinding cost is included in the forging price on commercial parts. It is of great importance to use the best steels available for the trimming punches and dies; the selection of steel depends on the forging material and the number of pieces to be made.

In hot-trim dies, the punch can be fitted to the contour of the lead taken off the forging dies. The punch must be made a good fit to prevent bending of the forging due to poor bearing points. Cast-steel dies, with Stellite welded on the cutting edge and ground to shape, are satisfactory for hot-trimming. Figure 287 shows a hot-trimming die in operation, and Fig. 288 the final upsetting operation.

The trimmer blades must be sharp and closely fitted and with the proper clearance between the punch and die blades. For mild steels, the clearance is usually 10 per cent of the flash thickness. It is advisable to grind a slight shear on the trim blades so as to distribute the cut and lighten the load on the dies and press, especially on heavy forgings which have considerable flash. It is important to relieve the blades $1/8$ to $3/16$ in. and $5/16$ to $1/2$ in. below the cutting edge, so that the forging may be easily located in the trim dies and the blades easily ground for sharpening. The inside clearance of the blades should be 5 or 10 deg. included angle.

Shoes for Trimming Dies.—Die shoes should be of standard design so as to expedite setup and decrease die cost. Convenient die handling should be arranged, such as by electric or gas lift trucks equipped with elevating platform. Setup tools can be conveniently carried on tables mounted on casters for easy moving. The table is provided with a drawer and shelves for necessary bolts and parts for clamping the dies.

Handling Raw Materials.—Steel warehouses must be compact, with adequate handling space and crane facilities and with convenient loading and unloading platforms. The stock is piled and arranged according to the type of material and is handled by an overhead traveling crane from rail cars or truck to storage sheds. The steel bars are

cut to the required forging lengths by "guillotine" and "alligator shears." Other methods of cutting bars to lengths, depending on the kind of steel and size of bars, include hot saw, cold saw, notching press, and an acetylene cutting torch.

Cleaning Forgings.—Excessive flash is removed by grinding. Scale is removed by use of the Wheelabrator Tumblast Machine, tumbling, and pickling methods.

FIG. 288.—Upsetting a radius-rod foot in the final operation.

Inspection.—With new developments and expanded production, the inspection department has an important problem to continue accuracy and ensure quality. "Leads" from completed dies are checked and submitted to customer for approval. The shape of the forging must be considered in checking "leads." Dies are sunk with $\frac{1}{64}$ in. plus, for shrinkage allowance, but forgings with lugs or shoulders prevent normal shrinkage of lead castings and this must be allowed for. Straight sections will shrink normally and can be measured with a

standard rule. A "lead" is a work sample molded in the forging die with hot lead.

Process inspectors are responsible for the interpretation and enforcement of manufacturing orders and must see that parts correspond with the specifications given on prints. Hammers that are producing parts not to specifications are stopped and reported to foreman for correction. Faulty dies are reported to the toolroom and engineering department, as well as to plant superintendent and chief inspector. Final inspectors check each part to tag and print and make a detailed report of rejected pieces. Parts are inspected, adjusted, and packed by the final inspector, thus saving extra handling.

The Human Element.—The way to increase production is not only to use modern equipment and engage additional workers, but also to show the men how to work efficiently, for example, by a well-organized training program. Also, orderliness and cleanliness should prevail throughout the plant. Each worker's mental and physical condition is reflected in the product of the company. To organize for better working conditions and leadership in safety will show in improved products, less labor trouble, increased efficiency, and fewer accidents.

COINING, SWAGING, AND EXTRUDING

Introduction.—For swaging, coining, cold-sizing, and extruding operations, presses of extra-heavy tonnage capacities are necessary. Die body sizes must also be extra heavy and constructed of tool steels of highly resistant strengths. Such steels are chrome-tungsten oil-hardening steel, which combine high hardness with maximum toughness, and the "air-hardening type" of high-carbon high-chrome steel. This latter steel is more difficult to machine than the first, and its resistance to shock is not so good, but it is used largely for high-pressure work.

Presses employed are of four types, each of which has its special application: knuckle-joint, eccentric shaft, percussion, and hydraulic. The type of press used depends upon the size of work and the interval of time necessary to complete the operation. Knuckle-joint presses have short powerful strokes but fail to provide sufficient dwell at the bottom of the stroke. However, this feature is available in all types of hydraulic presses. Hydraulic presses are employed on work having deep extrusions or for large cold-sizing and pressing jobs in which the extra dwell at the bottom of the stroke can be utilized to put a definite "set" in the work. Swaged and cold-sized parts are highly compressed; the metal becomes harder and more dense, and this

desirable condition may increase the resistance to wear on the part made as much as 80 per cent, as compared with similar machined parts.

Knuckle-joint Presses.—Of recent years the knuckle-joint embossing press has come into more extended use. Originally employed for coining money, it is now applied to cold squeezing, swaging, upsetting, embossing, and extruding. Bosses on forgings can be sized as well by coining as by machining. In fact, bosses can be "swaged up," or raised above the surface of flat stock, which is an operation practically impossible, or very expensive, by any other means. Pressures up to 100 tons per square inch can be applied to the material. The limitation óf the knuckle-joint press is its short stroke. Modern knuckle-joint presses involve forced-feed lubrication systems at all points where heavy pressures on the bearings or other moving parts occur. Above the slide are spring-loaded rods so that the upper block will yield when adjusting the wedge. Capacities range from 25 to 2,500 tons.

Types of Swaging Dies.—There are four general types: (1) progressive swage and cut-off; (2) swaging parts having a perpherical "draft" for hand removal of the work; (3) swaging and leaving an overflow flash, which is subsequently trimmed; and (4) confined swaging, or coining, in which the finished work is completed from a blank which has the same volume as the finished piece. In the last two types, it is necessary to use a positive ejector in the die to remove the work when the ram ascends.

Sizing Drop-forged Parts.—This operation is done on the working surfaces of steel forgings where finishing is necessary. It disturbs the metal very slightly. The metal movement is unrestricted, and the purpose is to squeeze the faces of certain bosses on unfinished forgings, to give them smooth surfaces and accurate dimensions. The result of squeezing the bosses is that better working surfaces are obtained than by milling them, because the metal is compressed and wear resistance is greatly increased. Furthermore, the hourly output from squeezing dies is more than ten times that of turning or milling operations on a similar piece of work.

Cold-sizing.—Bosses on steel forgings can be cold-sized by pressing as well as by machining if the pressure is great enough. Figure 289 shows the usual "setup" of die blocks and the principle used for cold-sizing four bosses on a forged-steel connecting rod. To avoid using excessive pressures the dies are relieved where no pressing is done, and a "draft" is provided along all edges of the work that are not squeezed to size. There is also a 45-deg. draft around the bosses to be sized, to facilitate removal of the finished work.

The closed height of the dies is checked by the surfaces of the blocks. These surfaces are in a plane coinciding with the longitudinal center plane of the work. Areas of the stop and the top and bottom surfaces of the block should be large enough to withstand three times the yield strength of the metal being sized. The closed height of the blocks checks the thickness to be sized, or dimensions T. Four bosses D are also squeezed to size.

Certain heavy-gage sheet metal blanks are cold-sized to produce uniformly rounded edges and planished surfaces and for other correc-

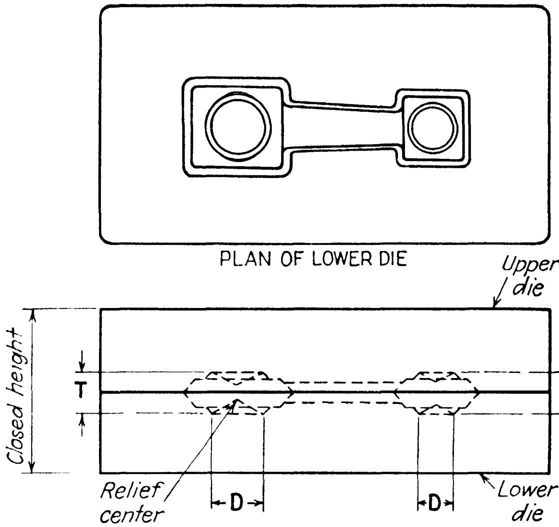


FIG. 289.—Forged bosses of comparatively large diameters are prepared with an impressed relief center for cold-sizing. This precaution prevents pyramiding, or the building up of metal toward the center of the boss, thus avoiding a slight hump at the center. The relief centers are exaggerated in the sketch.

tive purposes. Small work to be sized in thickness is usually milled about $\frac{1}{32}$ in. oversize, and larger work to half this amount. The dies used are similar in principle to the one described under Fig. 289 and descend to a sizing stop either on the die surfaces or on spacer blocks. It is good practice to select a knuckle-joint press having a factor of safety of three or more over the maximum work pressure.

A practical determination of the necessary pressure for cold-sizing is to squeeze the first pieces with the dies placed in a hydraulic press provided with tonnage gages. The mathematical computation depends on the following formula:

$$P = \frac{A \times S}{2,000}$$

where P = pressure required in tons.
A = area to be sized in square inches.
S = ultimate compressive strength of the work material per square inch.

Figure 290 shows the chart used when computing the safe areas of die blocks used in connection with cold-sizing operations. It gives the

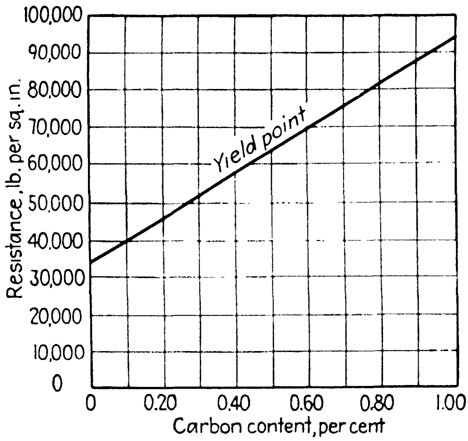


FIG. 290.—This chart shows the yield point of commercially annealed steel of various carbon content.

yield point of commercially annealed steels containing different percentages of carbon. This chart is useful for other purposes where the ultimate compressive strengths of steels are involved.

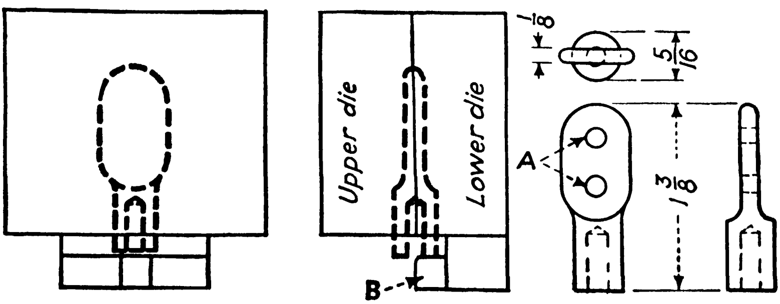


FIG. 291.—The dies. FIG. 292.—The work.

FIGS. 291, 292.—To release work from the dies, the swaged portion of this soft copper terminal has a semicircular edge to obtain "draft."

Scope of Cold-sizing Operations.—Besides the bosses on automobile connecting rods, those on the emergency-brake lever and steering-rod knuckles and even cast-iron piston rings have been cold-sized, and so have many other parts. As explained in bending and forming dies,

Chap. IV, there is an inevitable "spring-back" after forming the work which is sometimes difficult to control. In cold sizing, spring-back may be due to other causes than residual elasticity of the work material. It may be caused by elasticity in the die blocks, press frame, and bolster.

Swaging Copper Terminals.—In Fig. 291 a pair of die blocks is shown for producing the soft-copper terminal in Fig. 292. The blank is prepared by drilling one end hole and cutting to length. After swaging to shape, the holes *A* are pierced in another tool placed next to the swaging die. Stop *B* locates the blank endwise in the lower die.

Swaging with an Overflow.—Swaging with properly designed tools is probably the best method for producing small intricate parts in multiple uniformity. However, without some previous knowledge of swaging or experience that has shown the designer what can be done and what cannot, the final results may amount to nothing more than failure. If there is any question as to the practicability of swaging a given piece of work, it is best to use experimental dies for predetermining whether or not swaging will be successful.

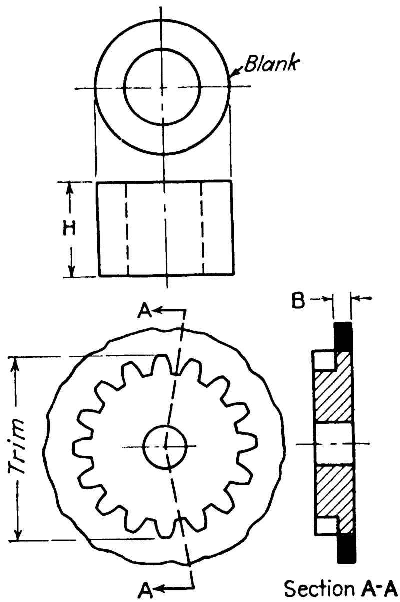


FIG. 293.—Small parts that must resist wear, such as this business-machine gear with the integral flange behind the teeth, are swaged by the overflow process in one press stroke and the irregular edge of flange is subsequently trimmed off in another die.

Swaged parts have a distinct advantage over those made by any other method. They are much stronger, practically wearproof, have bright smooth finishes, and are free of scales and burrs. Certain difficult designs of work cannot be produced except by swaging. A case is seen in the steel gear (Fig. 293), shown as it came from the overflow type of swaging die (Fig. 294).

The flange, or web, *B* behind the gear is an integral part of the teeth. Flange thickness is determined by the overflow space *B* between the closed dies. The flange is subsequently trimmed in a second operation die; trimming coincides with the outside diameter of the gear. This gear could be trimmed larger in diameter if the overflow flange were swaged greater in area. It could be trimmed with a higher step of

teeth, thus producing a cluster gear. These variations point out the possibilities in the designing of swaged parts.

A typical die layout for swaging and ejecting this gear, or similar small work, is shown in Fig. 294. The blank is "dead-soft" steel, and its outside diameter is slightly less than the root diameter of the gear teeth. The hole diameter is an easy fit over the vertical center stud in the lower die. Blank height H is determined by the volume of material needed to swage the piece and is easily found when using experimental swaging blocks during the initial trial operations.

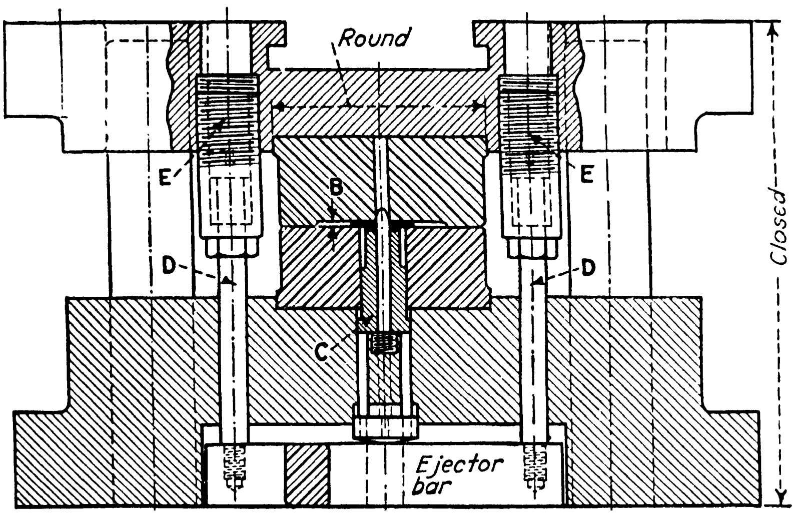


FIG. 294.—Swaging die for producing the gear in the preceding sketch. Tooth thickness of the swaged gear is determined by the registration of shedder C in the die shoe and the flange thickness by space B.

The lower die opening is of internal-gear shape and is broached and lapped to size. Shedder C is a sliding fit within the lower die; it registers in the die shoe at the closed height of the tool and at sufficient depth for swaging the thickness of the gear teeth. This tool is operated in a 200-ton knuckle-joint press, which is several times the necessary capacity to swage the piece.

When the press is open, the hole in the blank is placed over the vertical stud in the lower die. When the ram descends with the punch, contacting the blank, it squeezes the blank between the upper and lower dies until plastic flow begins. Continuing the squeeze, the metal is forced to "flow" into all the interstices of the die. The hole in the blank closes tightly around the central pin; the gear teeth are formed; and the tooth thickness is determined by the registration of the shedder in the die shoe. Surplus metal overflows into space B.

Work ejection occurs near the top of the ram ascent. Heads of screws *D* contact the bottoms of hollow adjusting nuts *E*. The screws are attached to the ejector bar and elevate it as the ram ascends. When the shedder is flush with the lower die face, the work is ejected. The center pin is slightly tapered toward its point to aid ejection. All interior surfaces of the dies are smoothly polished.

Swaging dies cannot be used until thoroughly cleaned with gasoline and perfectly dry. If a small portion of oil remains in the die it will

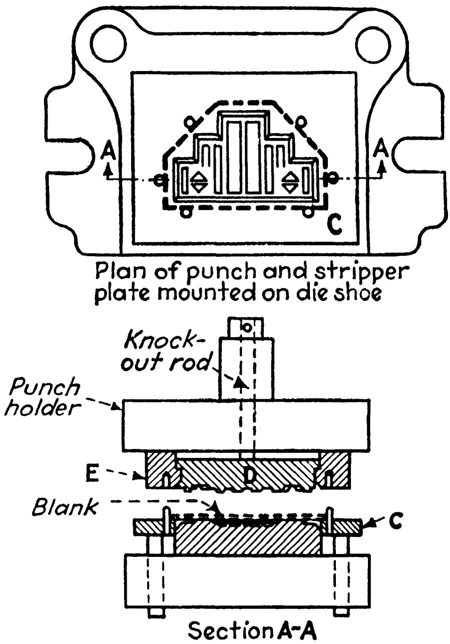


FIG. 295.—Shedder *D* also acts as the coining punch in this inverted die, which forms, draws, and coins sharp corners on the escutcheon plate shown in the next figure.

cause trouble when attempting to swage; it may fracture some part of the tool.

Coining Dies.—Coining is a high-tonnage operation. Under hundreds of tons pressure, the die forces metal by plastic flow into various embossed designs of raised panels, beads, depressions, ornamental outlines, and sharp corners. Coining dies include not only the mintage of money, medals, medallions, and jewelry parts but also the forming and embossing of buttons, locks, ornamental hardware, designation plates, and escutcheons.

A die in which the coining principle predominates is represented by Fig. 295. The operation consists of drawing, forming, and coining

the ornamental escutcheon plate, one-half of which is shown in Fig. 296. The die is an inverted type. It is so made in order to secure easy delivery of the finished piece by action of the vertical knockout rod shown through the punch shank.

The punch is surrounded by stripper pad C, upon which the blank is located within a "nest" of pins. When the ram descends, the pad becomes depressed against the large vertical pins which rest on a heavy spring plate in the bolster. The upper coining punch is shedder D, and it is a sliding fit within drawing punch E. When the die closes, with a blank between the blocks, the work is drawn down within its edges, the panels are embossed, and the sharp corners are coined. When the ram ascends, pad C follows up and raises the finished work from the lower block. The work adheres within die E, which carries it up to a point where the knockout depresses the shedder and delivers the piece. This operation requires a pressure of 150 tons. The apparently excessive tonnage is necessary for coining sharp edges along the raised portions of the work, a section of which is shown at B-B in Fig. 296. The metal is squeezed thinner on the sides of the raised portions, and by thinning these sides the overflow of metal is used for producing sharp corners.

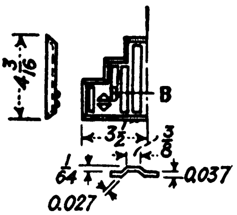


FIG. 296.—Sides of the raised portions of this escutcheon plate are squeezed thinner than the metal gage, as shown by the given dimensions, to provide a surplus of metal flow for coining sharp corners.

Twelve right-angled beveled corners in the outline are *drawn*, while the straight sides between the corners are being formed down. The attached flange around the work perimeter is subsequently removed in a second operation trimming die.

Extruding Aluminum Shells.—The process for extruding cold aluminum shells is simpler than drawing them. The blank used is extra-soft annealed stock. Figure 297 shows a typical extruding die and the principle used in forcing an aluminum blank to form a shell. This is a good example of what can be done because of the plasticity of metals.

The punch is shown in three of its operating positions. At A the blank has been placed on knockout pad D in the bottom of the die, while the punch is up. At B the punch in descent has contacted the blank, and its impact increases the temperature of the material. Continuing in descent, the punch forces the metal into a plastic state and causes it to rise and fill the space between the punch and die. At C the punch is carrying up the finished shell, followed by the knockout pad. The knockout pad is operated by a cam underneath the

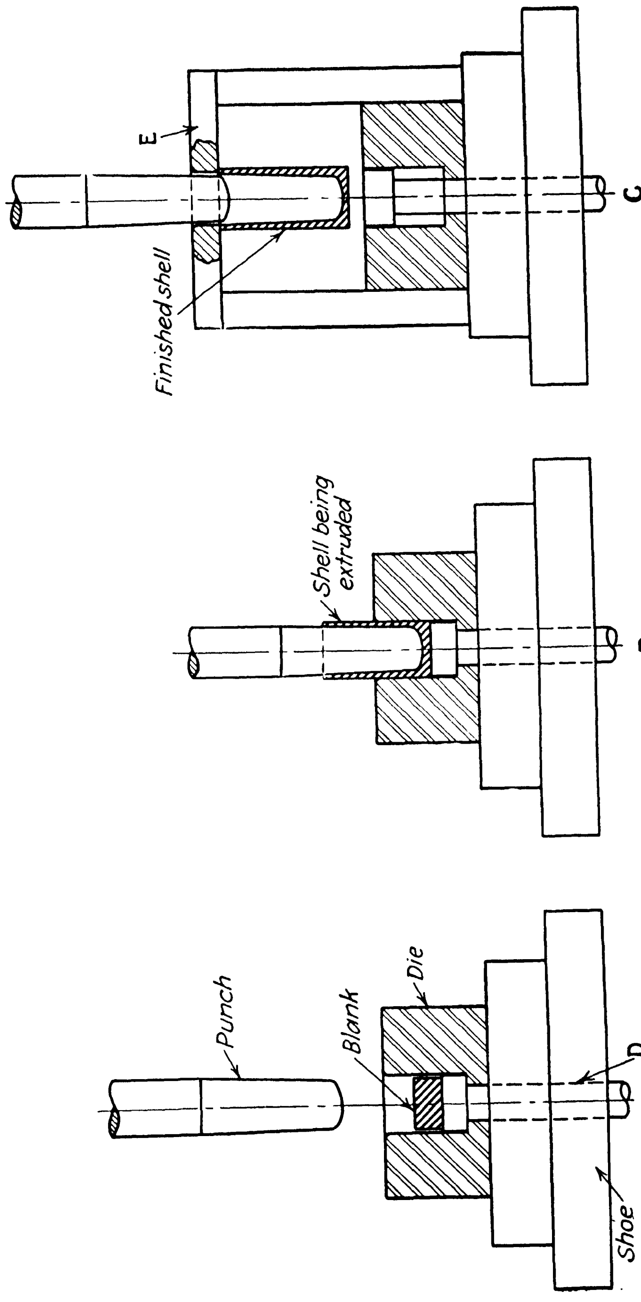


FIG. 297.—Extruding an aluminum blank which is laid in the recess of the die at *A*. The pressure on the nose of the punch, when it descends and contacts the blank and continues to descend, forces the metal to "squirt" up and "hug" the punch, which forms the shell between the punch and die.

press. The shell is stripped from the punch by contact under the positive plate *E*. The entering end of the punch is slightly smaller in diameter than across its top to facilitate stripping. An air vent hole through the punch cannot be used because the metal would flow into it. Because of taper on the punch, a vent hole to facilitate stripping is not necessary. Shells are blown from the press by a jet of air.

Blank thickness and length of press stroke control the shell height. The limit is approximately seven times the shell diameter, depending, of course, on the diameter and ductility of the material. The thickness at the closed end of shells is determined by the depth at which the punch enters the die, while the shape of the closed end is determined by the cross-sectional design of the tool members. The cross-sectional contour of the shell body can be any reasonable shape and is usually made of uniform thickness throughout its length.

The ordinary extruding press has a compact double-sided frame similar to the conventional straight-side presses. It is built with either single or double gears, which impart slow speed and great power to the punch travel. It has a crank stroke, and the largest presses require a driving motor of 50 hp. By hand feeding, a possible output for small shells is about 2,000 per hour. With an automatic feed, this output may be doubled.

Extruding Collapsible Tubes.—This operation is similar to extruding aluminum shells, but the press construction is different, and the hourly output is only half as great. Collapsible-tube presses are built both vertical and horizontal. The vertical machines belong in the arch- and pillar-press classes. All of them are back geared for a slow and powerful travel of the punch. The operating mechanism is a knuckle joint which imparts to the punch that smooth and easy action so necessary in producing collapsible tubes used for dentifrices, shaving creams, pastes, artist's tints, etc.

These presses are built in three sizes, 30, 60, and 130 tons capacities. The press strokes are from 4 to 4½ in.; the diameters of tubes are ¾, 1¼, and 2 in.; and the lengths are 6 in. In operation, a tin- or lead-alloyed blank or disk is placed in the die, and a swinging arm automatically carries the punch directly over the die and blank. The ram, in descent, forces the metal up around the punch as is shown in Fig. 297. The punch sides are slightly tapered outward above the nose to facilitate removal of the finished work. When the punch ascends, the die knockout gradually raises the tube from the die, so that the tube clings on the punch. As the ram continues to ascend, the punch is automatically swung outward into a convenient position where the finished work can be stripped off by hand.

CHAPTER XIV

WELDING FOR WAR AND PEACE

Die Products Can Be Welded or Brazed Together to Make One Piece

Welding and Die Engineering.—Welding, in its various forms, is often used as an auxiliary operation to presswork. A practical knowledge of the several methods used in welding and brazing is as important information for the die man as the design and construction of press tools. Cases arise in which several parts that are blanked, formed, or drawn separately must be subsequently united so as to become, for all intents and purposes, the same as though made from one piece of metal. (See Plate XXXV, page 444.)

This chapter does not attempt to deal with all the complex welding processes, with automobile-body welding, or with the tools used in such large heavy work as air conditioners, refrigerators, army tanks, airplanes, or farm implements. Many operations done in large dies, however, often suggest new ideas to the man engaged in small-die operations. He can often use ideas that have originated in shops where heavy presswork is done. At times, he may find it necessary to weld together the ends of slitted strips of various widths, in order to make one continuous length for coiled stock or to join the edges of narrow sheets to make a wider one.

Spot Welding.—The easiest method for fastening sheet metals together is by spot-welding them. This method is sometimes called "resistance welding," which indicates how the operation is accomplished. It means that the resistance set up against the flow of an electric current, by the work sheets that lie between the electrode points, fuses the metal and thus makes a weld at a spot which is approximately equal to the diameter of the electrode points. The pressure exerted between the electrodes, actuated by a foot treadle under the machine, completes the weld.

Spot welding is a high-speed, cheap operation. Furthermore, the required tools and the machine itself are comparatively inexpensive, and the operator need not be particularly skilled. The fault in this method is that no one knows whether any individual spot weld will hold together. In the ordinary shop, there is no way of knowing how strong the spot is unless it is pulled apart, thus destroying the

work. Where the welding area is large, this trouble sometimes can be overcome by making more spot welds than are really necessary. While a few of the welds may fail to fuse, the workpieces will still be securely attached by the other welds that fused properly. Another way is to make the welds hotter than necessary, especially in the case of welding mild steel, which will take a great deal of abuse in this respect. However, this sort of welding is unreliable. It could not be considered good work for highly stressed structures. To overcome these difficulties, the Budd plant in Philadelphia has developed a very efficient recorder for testing the strength of welds. They have also developed portable welding "guns" and high-speed multiple welders.

Recorder for Testing the Value of Welds.—When the recorder is attached to the welding machine and the operation proceeds, it automatically scribes a short or long line on a paper tape. A line is made for each weld. A short line indicates a weak weld; if it is long, there is an oversized weld made, or perhaps a burned one. If the line is over or under length, a bell rings, and the machine stops until corrections are made. The allowable welding strength tolerance is about 10 per cent, and the strength variation of riveting is no better.

"Shot-welding."—The "Shot-weld" process was developed several years ago in the Budd plant. It is used exclusively for welding together sheets of Stainless steel. In this process, a recorder is attached to every welding machine, and the machine is adjusted to produce welds of any reasonable shearing strengths. If the strength of the weld varies beyond the allowable limits either way, the bell rings and the machine stops.

Stainless-steel alloy known as 18–8 lends itself to Shot-welding more readily than ordinary steels. Its electrical resistance is eight times greater, and its heat conductivity 40 per cent less than ordinary steel. Stainless steel cannot be spot-welded without difficulty. The reason for this is the uncontrolled heat that accompanies spot welding. If the welding heat exceeds 1200 to 1600°F., and remains there for any appreciable time, carbides are precipitated out of the solution, and the metal at that point is no longer Stainless steel. On the other hand, if the metal is not brought to welding temperature, no fusion occurs.

In the "Shot-weld" process, the metal is brought to welding temperature so quickly, remains there for so short a time, and is cooled so rapidly, that not enough heat is generated to precipitate the carbides, and in chemical and physical properties the metal, after welding, remains Stainless steel. This process, because of its great speed in generating heat, is called the "Shot-weld." A portable gun somewhat

like an air hammer is used in the process. The operator pulls the trigger, and the contact time is automatically controlled by the welding machine.

Lap and Butt Welds Compared.—The objection to any spot-welding process is that the sheets must be lapped over one another, and, even though the joint is well worked down, it is always perceptible. It is, however, excellent for some types of work where a smoothed lap-welded joint is permissible. Naturally this method is not satisfactory where perfectly smooth joints are wanted, and butt welding was deemed the most desirable for joining the edges of narrow sheets to make a wider one.

If the edges of two sheets of ordinary steel are placed closely parallel to one another without touching, and a high voltage of current is turned into each, it follows that the current will attempt to jump from the edge of one sheet to the other. In doing this, it will naturally follow the shortest path, or the narrowest part of the gap between the two sheets. This narrow part is usually caused by a projection, burrs, or some other irregularity in the contour edges of the sheets. This projection, having insufficient capacity to carry the current load, gets hot and melts. But the moment the narrowest place has burned as wide as the next narrowest place, the current starts to jump across at the latter place. Finally, all projections between the two sheets are burned or melted away evenly, so that the gap is parallel its entire length.

Because the amount of current is adjusted to the carrying capacity of the sheets of metal, and the current is jumping across the parallel gap for its entire length, the sheets do not burn or melt so rapidly as they did when only a part of the sheet was trying to carry the entire load. Sparking has practically ceased, and the two edges are now in a plastic state. The welding machine automatically brings the two edges together near enough to touch and to raise a light ridge, or seam, and the current is turned off at the same time. It should be understood that all these operations occur in the short interval of only a few seconds of time. The two sheets are now fused together, making an even solid joint that is not visible when the seam has been cleaned. Cleaning the seam is done by milling or grinding and sometimes by chiseling and buffing.

The Economy in Butt Welding.—Where low-carbon steel is used, the metal does not harden at the joint, and it will draw in a die just as readily as at any other part of the sheet. The interest of the man in the small field in this process is that irregular surfaces can be joined just as easily as straight ones, if the edges are held in the proper fixture.

Many parts that now have to be spun can be drawn in sections and butt-welded together more economically than spinning them. Aluminum and its alloys are welded by oxyhydrogen or oxyacetylene torches, but a proper flux is necessary to eliminate the surface oxide film. The flux can be obtained from the agents of the manufacturers of welding apparatus.

Butt-welding Automobile Bodies.—Although very good machines have been developed for cleaning butt-welded seams, it has been found just as satisfactory, in auto-body work, to spot-weld a joint along depressed flanges and then fill solder in the groove thus formed. This method is used, of course, only where the conventional spot-welded lap joint is objectionable, and it is only a very small part of the total welding of a body.

An unfortunate disadvantage in using the butt-welding system is that the machine for taking the stampings is necessarily large and therefore stationary. This means that an awkwardly shaped body assembly must be carried to and from the machine. In spot welding, the body remains in one position, as the operator can get all around it with his portable welding gun.

Brazing Multiple Joints Electrically.—A method for joining together smaller parts than the large sections of automobile bodies is done in an electric furnace. This method is employed for certain subassemblies in refrigerators and for other partial assemblies of piece parts in semilight manufacturing. The electric furnace is one of the many products of the General Electric Company, and by its use stampings, castings, and machined parts can be welded into an assembled unit without warping, distorting, or discoloring the parts.

The surfaces of the parts to be joined are placed tight together, and wherever possible snug fits are made to obtain strength and tightness in the joints. Tack welding, staking, peening, and similar operations are resorted to for holding the parts temporarily in place so that the proposed assembly will be self-supporting in the furnace. Copper in some form is placed near the joints and flows into them under the heat of the furnace.

Copper is generally used for brazing steels, but brazing metals of lower melting points are used for joining nonferrous parts. The brazing metals are applied at the time of assembly of the parts. They can be applied in any convenient form, such as wire, chips, ribbon, powder, or paste. A very satisfactory copper paste can be made for daubing around joints to be brazed by mixing pure copper with lacquer and a thinner. Copper brazing is done at a temperature of about 2100°F., in a reducing atmosphere which is introduced from a separate

gas converter by partially burning coke or natural gas. The furnace temperature is about 100°F. above the melting point of copper, but is, of course, considerably lower than for the steel or cast-iron parts.

Threads and similarly exposed parts may be protected against the flow of copper by painting them with chromic acid, aluminum paint, or whiting. Where it is desirable to remove surplus copper from the surfaces adjacent to the joints, it may be done by pickling or by deplating in an electrolytic sodium, cyanide, or ammonium nitrate bath. The amount of copper removed depends upon the strength of the solution and the length of time in the bath.

New Welding Technique.—A greatly increased production of vital welded war products is forecast by a new procedure called "Fleet-Fillet Welding," which has been announced by The Lincoln Electric Co.

Before adoption of welding, the construction time of a large warship was approximately four years. Now, it is approximately two and one-half years. Today, owing to welding, the nation's shipyards are turning out war craft at unbelievable speeds—for example, cargo vessels of the "ugly duckling" type at the rate of a vessel every 3½ days and high-speed subchasers at the rate of one a week. Similar increases in production speed have been made possible by welding of planes, tanks, guns, etc. Now, through the application of this new welding technique, the customary time for constructing naval, military, and industrial equipment can be still further reduced.

A comparison between the "Fleet-Fillet" technique and the conventional method showed that, with the new method, the penetration of the weld beyond the root or the corner of the joint was considerably better. Moreover, the size of the weld was considerably less, yet the strength was equal. In one type of joint, the conventional method required 0.37 lb. of electrode, whereas the new technique required but 0.26 lb. Since such a saving may amount to as much as a million pounds per month to industry, the new technique is also important to the war effort through the conservation of electrodes. In the same joint, the electrode cost per foot of weld was 2.2 cents the conventional way, and but 1.5 cents the new way. Because of time saved, the labor cost was but 4.0 cents by the new technique as against 5.8 cents the old way.

Resistance Forge Welding.—This is a new process in the art of spot welding. Developed by Progressive Welder Company, it permits welding together of heavy steel and iron sections almost as readily as light sheets. Heretofore impossible with conventional equipment, this process opens additional fields for resistance welding in the assem-

bly of heavy structural shapes. This method promises some interesting developments in expediting the manufacture of heavy equipment for war.

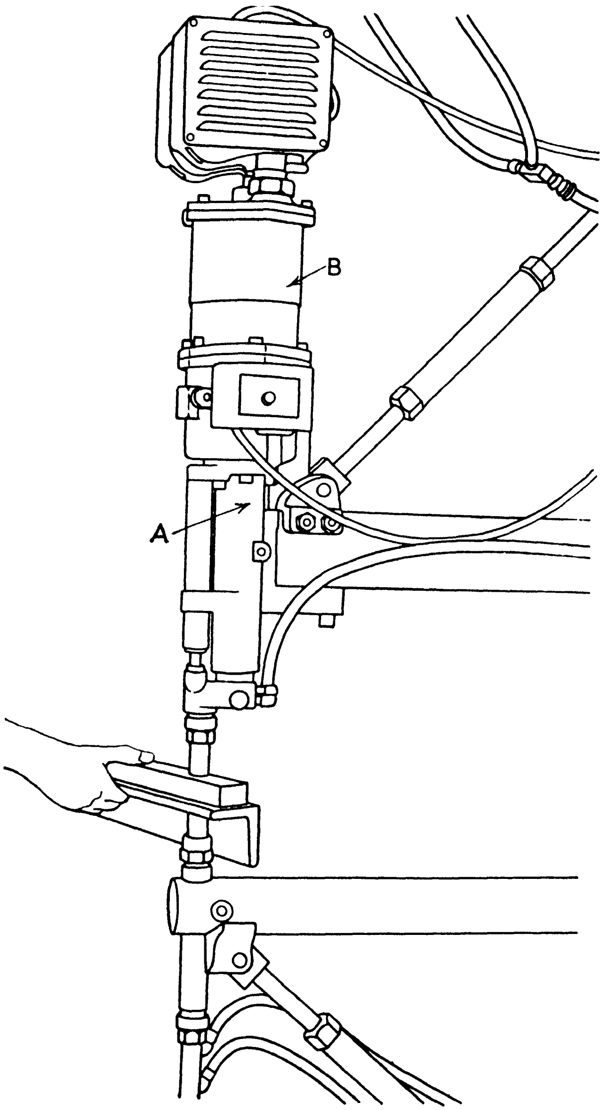


FIG. 298.—Illustrating the setup for the new process of resistance forge welding. With this equipment heavy sections of steel and iron can be firmly attached to one another.

In principle, this process harks back to the original method of welding as done by the blacksmith, known as "ordinary forging," from which

it takes its name. In the setup shown in Fig. 298, pressure is furnished by the lower cylinder *A* of the compound air-hydraulic booster, which is mounted on the upper arm immediately above the electrodes. This

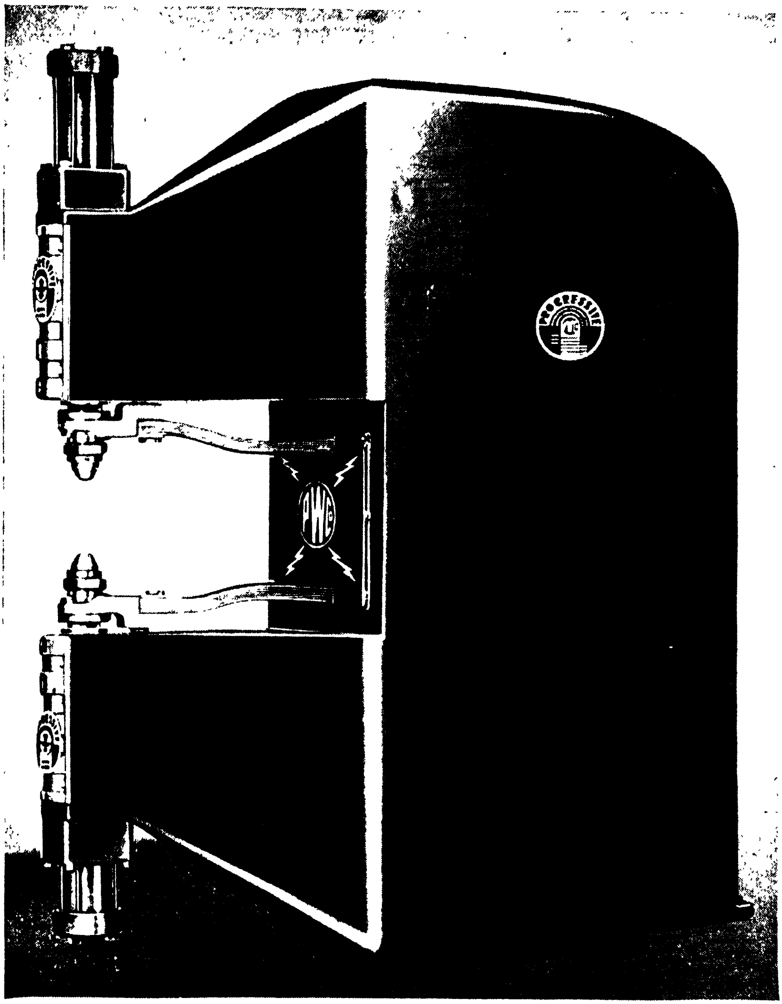


Fig. 299.—This machine "thinks for itself." The new progressive Temp-A-Trol forge welder, which eliminates the effects of many of the variables that control weld quality, heat-treats and welds simultaneously and is automatically self-compensating.

booster supplies the initial pressure which, together with an interrupted welding current, brings the work surfaces into intimate contact. The piston of upper cylinder *B* of the booster is then brought into a rapid reciprocating action which imparts "hammer" blows directly on the electrode over the work. Thus, the weld is practically "forged"

by the hammering action of B, while the work is constantly clamped together under the pressure of A.

Welding Machine for Heavy Plates.—In this patented welding machine, Fig. 299, the temperature at the weld itself automatically controls the weld, heat-treating current, and operating cycle. It is completely self-compensating for variables such as difference in metal thicknesses, induction and short-circuiting losses, or presence of scale.

Designed for resistance welding of heavy sections of special alloy steels, such as homogeneous and face-hardened armorplate for ship-

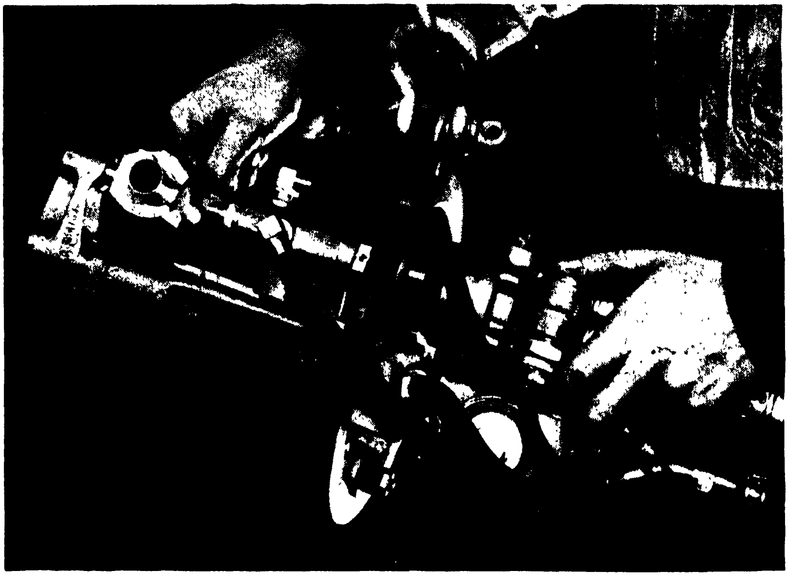


FIG. 300.—Illustrating the method employed and the fixture design for spot-welding on Stainless-steel tubing. (*Courtesy of Progressive Welder Company.*)

building, it spot-welds and heat-treats at the same time. With completely automatic control of weld, heat-treating, and annealing cycles, this machine reduces the worker's job to a mere setting of the dials for the actual temperatures and conditions desired.

Detailed information about this new process will be furnished, at present, only to organizations engaged in, or contracted to engage in, war production work.*

Welding Stainless-steel Aircraft Parts.—Figure 300 shows a copper electrode made in the shape of a "nest" to hold the work. This design must be used when the work is of other shapes than flat. In this case, a thin-wall Stainless-steel tube, $\frac{7}{8}$ in. outside diameter, is

* Progressive Welder Company.

held in a form protecting the welding electrode, while welding pressure is applied for spot-welding it to a strip. The strip is also of Stainless steel.

Spot-welding Steel Truck Bodies.—Figure 301 shows how easily large welding units can be handled for spot welding in difficult places which would otherwise be impossible to reach. The electrodes are provided with sliding contacts. This feature makes it possible to

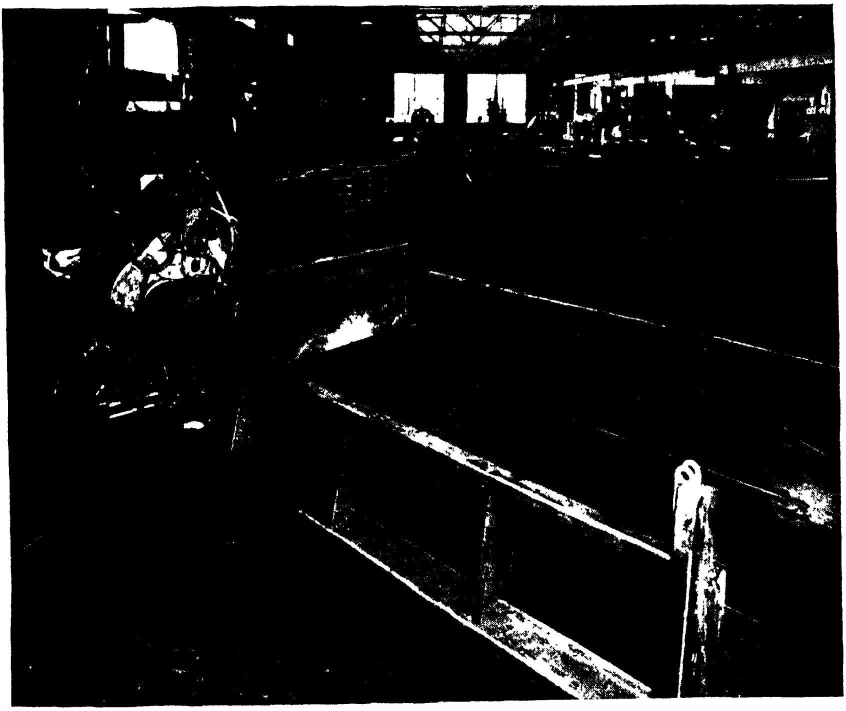


FIG. 301.—Spot-welding the front end and sides in a large steel truck body. This heavy welding unit is suspended from above and is moved easily to any point around the work. The support is either by rollers on an overhead rail or by an ordinary portable crane. (*Courtesy of Progressive Welder Company.*)

weld successfully in close quarters. The sliding contact also eliminates the usual wear on connecting cables. With this equipment, spot welding can be done at any longitudinal position within this steel truck body. This method ensures work of high bodily strength without the necessity of attaching unnecessary structural shapes.

There are many other practical applications for this welding unit, especially in aircraft work, by using the same type of welder designed in different sizes, shapes, and weights. Gusset plates can be welded in place, assembled bomb racks spot-welded, and an endless variety of

work can be done on automobiles, washing machines, kitchen sinks, stoves, refrigerators, cooler cabinets, etc. This device has the advantage of being extremely mobile; it can be readily taken to the work anywhere in the shop, instead of heavy awkward work having to be moved to a welder at a fixed position. This results in tremendous saving in time and expense.

"Refrigerated" Spot Welding.—The Weltronic "Frostrode" welding process has just been developed for handling tough welding jobs where water cooling has proved inadequate, such as in welding of *aluminum* or *heavy steel* sections. Aluminum is one of the most difficult metals to weld because of its low electrical resistance and the consequent high current values required for welding. Since (Heat generated

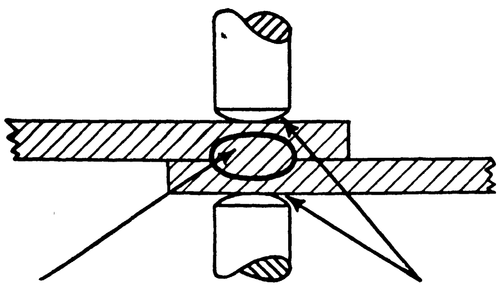


FIG. 302.—In spot-welding operations, surface heat causes the work to alloy with the electrodes or "pickup." The heat also is responsible for electrode "mushrooming," or weak spots and burning of the work material. The desirable results illustrated above are accomplished by "refrigerating" the electrode holders instead of using the old-water-cooled system. (*Courtesy of the Weltronic "Frostrode" Welding Process.*)

at electrode) = (current)^2 × (resistance at electrode), it is extremely difficult to prevent "alloying" of aluminum with the electrode, or "pickup," as this condition is called. The remedy for this difficulty is refrigerated spot welding as illustrated and described under Fig. 302.

Assembling and Spot-welding Bomb Fins.—Bomb fins are assembled and spot-welded at the rate of 300 per hour on this semiautomatic dial-feed welder. Except for loading, unloading, and clamping, this turntable-type welder is entirely automatic. In the illustration, Fig. 303, body cones are taken from a supply alongside the machine and placed on the dial, which is faced with copper. Fins from a supply shown in center of dial are located and clamped by the operator. The machine automatically indexes and makes 20 spot welds per piece or a total of 6,000 spot welds per hour.

One of the Lines behind the Lines.—A fixture for assembling and spot-welding bomb racks is shown in Fig. 304. A "Progressive" hydraulically operated portable spot-welding gun is used to make a total of 64 welds in the corners, ends, partitions, and braces of each

rack. The gun and hose connection are plainly shown in the cut. The work is securely held in each fixture by the four clamps shown. The fixtures are similar to those used in assembling and spot-welding cabinets, stoves, sinks, ranges, etc., but are of more simplified design.

As indicated in the illustration, this setup is for operation by three men, a welder and two helpers, and is designed to turn out approximately 200 racks per hour. It is observed that the work in the fixtures

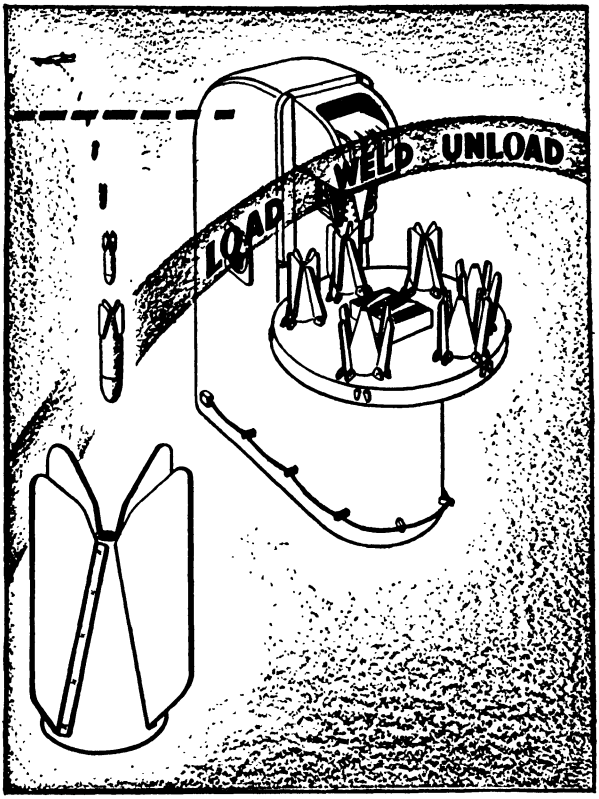


Fig. 303.—This is a "Progressomatic" dial-feed welding machine for assembling and spot-welding bomb fins. (*Courtesy of Progressive Welder Company.*)

is moved along an assembly line over a series of roller conveyers. This type of conveyer can be obtained commercially.

Spot-welding Army Helmets.—The manufacture of steel helmets for the army is illustrated and described in Plates XXXVIII and XXXIX, pages 447, 448. The helmets are drawn to shape in the pressroom. Next, they are transported by a chain and monorail to an assembly room where reinforcement strips are spot-welded around the rims.

Spot Welding with Rollers.—Spot-welding machines have been experimented with in which the electrodes were attached and revolved

on rollers. The obvious advantages of this design are continuous operation, cleaning the welding points while they revolve, cooler electrodes, and a highly increased output. This idea will probably be further investigated by some inventor in the future.

Spot-welding Thin Hard Sheets.—For difficult metals to weld, such as silicon steel and other hard "scaly" metals, if the sheets are very

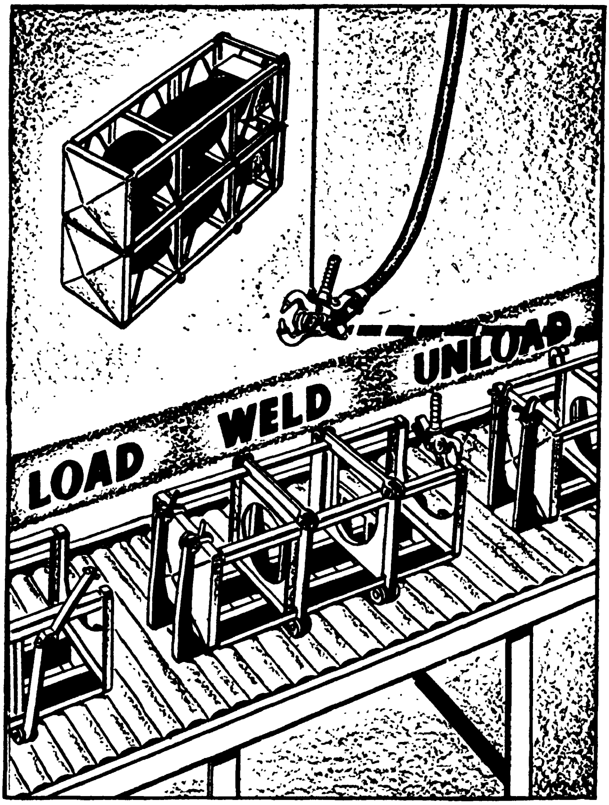


Fig. 304.—Method of assembling and spot-welding bomb racks in fixtures that are passed along an assembly line over a roller conveyer. (*Courtesy of Progressive Welder Company.*)

thin, the end edge of the upper sheet is first "prick-pointed," the points being about ¾ in. apart. The points are embossed in a cheap die and are raised about 0.010 in. above the sheet. This sheet is then placed, points down, over the other sheet and clamped between flat copper electrodes. This clamping action causes the embossed points to weld into the other sheet. By using sufficient pressure on the electrodes, the points are caused to fuse and the sheets are spot-welded flat together and produce very satisfactory work.

PLATE VIII.—Spot-welding airplane parts. With its customary efficiency, the automobile industry has rapidly changed to the production of aircraft planes and parts. This photograph was taken soon after Pearl Harbor, at the Briggs Manufacturing Company's plant in Detroit, Mich., where automobile bodies were formerly made for Chrysler and Plymouth cars. Here is a former automobile worker spot-welding a Duralumin duct for airplanes. He is using a special welding machine that was quickly developed for this purpose. (*Acme photograph.*)

PLATE IX

Spot-welding Stainless Steel

Stainless steel can be welded today virtually as easily as ordinary steels. There is a wealth of background in large- and small-scale spot welding of stainless steel assemblies incorporated in the machine shown on the opposite page. Furthermore, this same equipment can be used effectively for producing better welds with other steels, thus eliminating the need for "special-purpose" welding equipment.

In the assembly spot welding of the airplane cowl sections of Stainless steel, on this pedestal-type welder, will be seen the interchangeable offset electrodes and the adjustable lower arm which provides access to "difficult-to-get-at" spots. Stainless wing spars are also assembled by spot-welding the parts together on this type of a pedestal welder. However, when the parts are too cumbersome to be readily handled on a pedestal welder, a portable "pinch gun" is used which is operated by the same set of controls as incorporated in the pedestal machine.

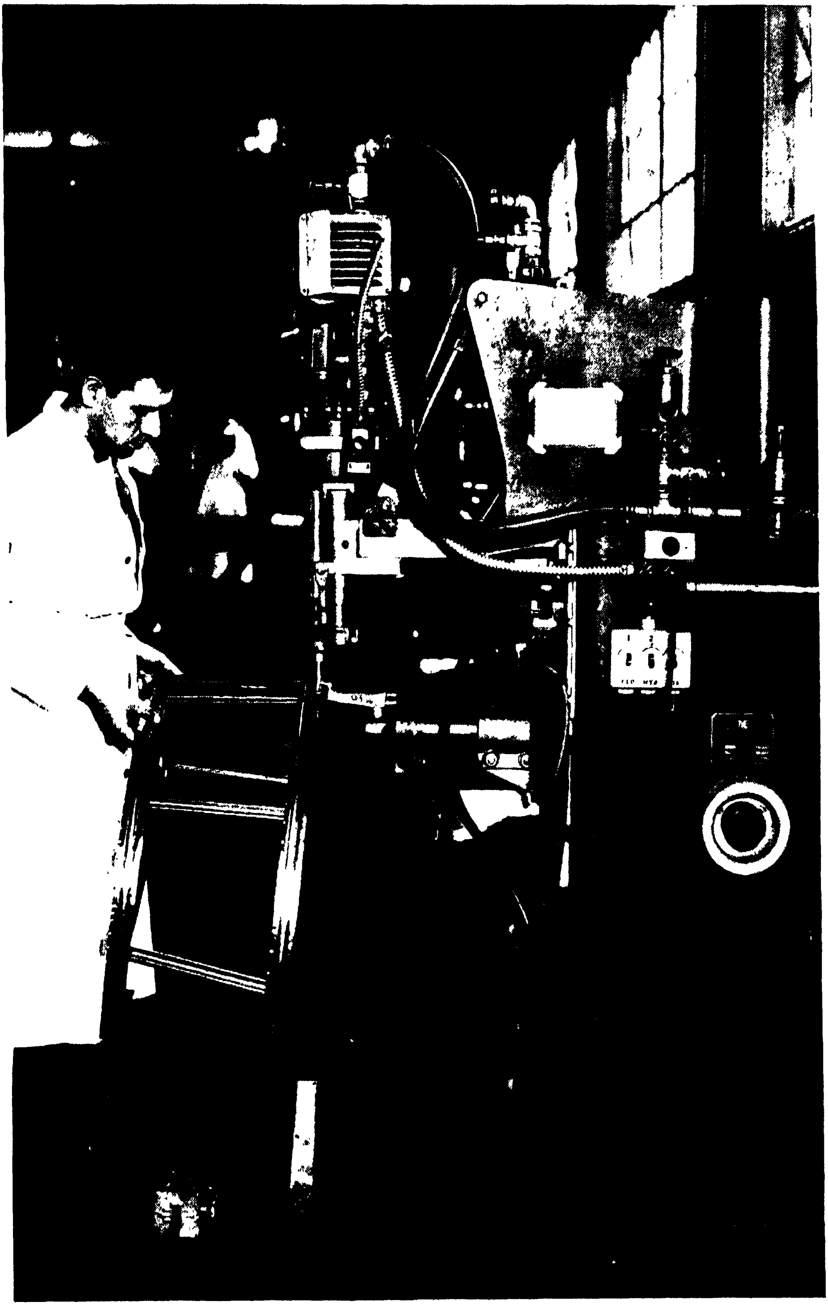


PLATE IX.—Spot-welding airplane parts. Assembly spot welding of airplane cowl sections of Stainless steel. (*Courtesy of Progressive Welder Company.*)

PLATE X

Double-shuttling Welding Fixture

Welding the reinforcements on ammunition box ends is greatly speeded up by using this hydromatic welder and two station fixture. The idea is seen in the photograph reproduced on the opposite page. At the right of the welding head is a sample of the assembled part shown standing up. The operation is to weld the two reinforcing channels on a flat plate box end. The fixture is designed to operate on the shuttling principle. Only two stations are needed, and they are positively attached on the same slide.

Under the welding head is seen the left-hand fixture loaded with the work, and the parts have just been spot-welded together. In the fixture at the right, the channels and box end are dropped into place and then clamped. Next, this fixture is shuttled toward the left and under the welding head, where 16 spot welds are performed simultaneously. However, while this assembly was being positioned for welding, the left-hand fixture was moved out from under the welding head, the previously welded box end was removed, and the parts for another assembly were clamped into place.

The fixture is then shuttled back toward the right, where the second welded assembly is removed and parts for the next box end are put in place. While this is being done, the assembly in the left-hand fixture is welded. Thus the cycles are repeated *ad finem.* There are two loading stations, but only one welding position, and no time is lost in loading because welding is done at the same time. The production rate is approximately 300 assemblies per hour.

The shuttling principle used in this fixture has also been successfully applied in press-tool assembly work. When pieces are to be folded over and then clinched, when parts are to be riveted together, and for certain die operations in which two or more work pieces are involved, fixtures of this type can sometimes be used.

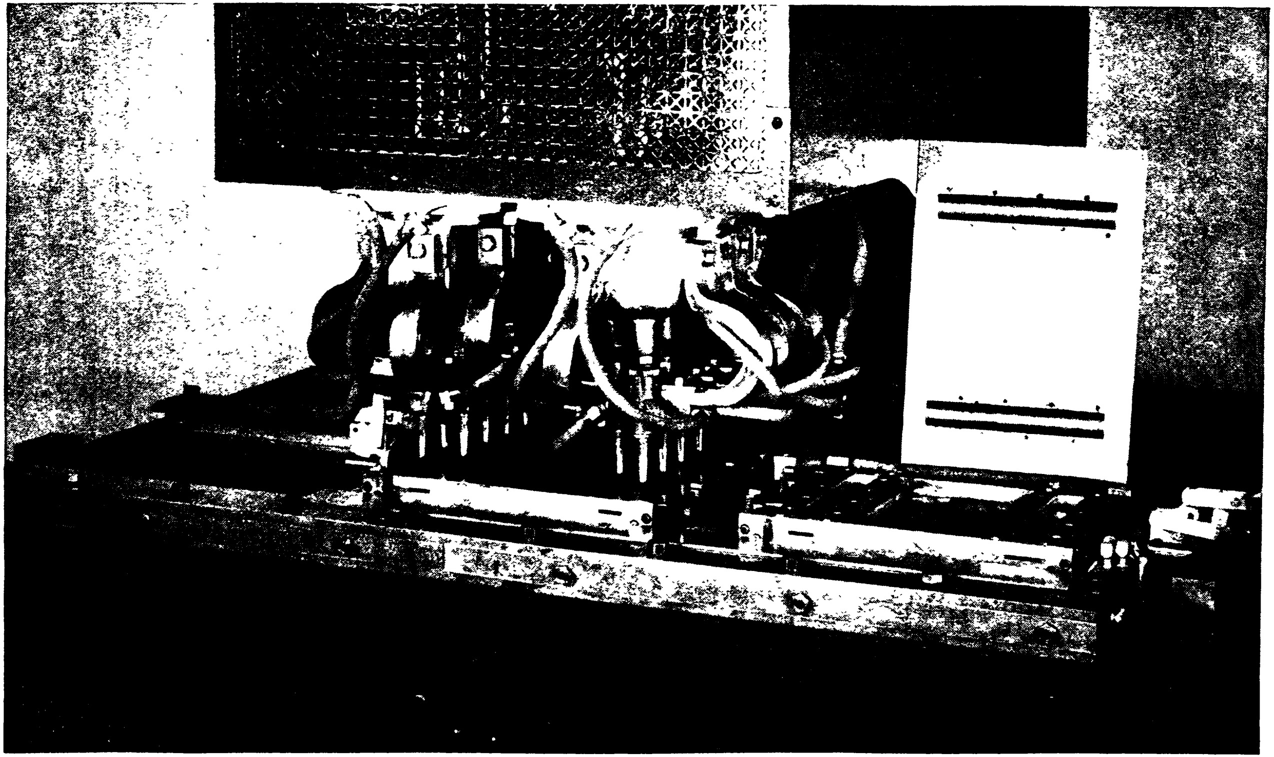


PLATE X.—A high-speed spot-welding fixture. Hydromatic welding machine with a two-station automatic fixture for spot-welding and assembling ammunition box ends. Sixteen spot welds are made simultaneously. (*Courtesy of Progressive Welder Company.*)

CHAPTER XV

MISCELLANEOUS PRESSROOM EQUIPMENT AND MATERIALS

SAFETY APPLIANCES

Safety Employees.—One of the problems confronting manufacturers of war equipment is the difficulty in finding careful and experienced men. Of course this situation was expected from the start. Even in departments where no machinery is used, the shortage of reliable help is discouraging, but in the machine departments, and especially in pressrooms, it is also tied up with a certain risk of accident for the inexperienced man.

However, the characteristics of a safe driver of an automobile and a man who can operate machinery safely are so nearly parallel that it is well to pause to consider them.

Examining Inexperienced Help.—There are two good recommendations for an inexperienced applicant who seeks work in a machine shop. (1) Has he previously been engaged in doing some other kind of work on machines? (2) Has he been an automobile driver for a certain number of years without being involved in a serious accident? The last question has uncovered several interesting facts in regard to the prevention of automobile accidents.

It is a well-known fact that the cause of accidents depends largely on the psychology of the driver. A good driver has a certain indescribable "feel" that seems to flow into his mind through his hands on the steering wheel. It tells him just what he can or cannot safely do in driving his machine. A "safety-first" employee around machinery has the same kind of an intuition.

Causes of Accidents.—It should be known by this time that drivers who lack a certain "sixth sense," or a quick mechanical understanding of conditions and positions of other cars on the road, are the trouble makers. They do not seem to feel the responsibility of driving, or to judge correctly the relationship among speeds, time, and distances. Add to these shortcomings a slow reflex action and faulty vision, and we have an excellent prescription for the causes of accidents. Accidents attributable to these causes mount ad infinitum. A faulty

driver may have a "perfectly good" operator's license and numerous "inspection tags" pasted on his windshield, but neither of these will prevent the inevitable accident.

The worst part of this sad story is that all these deficiencies may be brought along by such an employee directly into the shop where, for the first time, he is brought into personal contact with high-powered machinery. Therefore we must conclude that all the prerequisites of a good automobile driver must also be included in the man who desires to become a reliable journeyman mechanic.

When Crankshafts Break and Flywheels Fall.—The motion of heavy flywheels may crystallize the crankshaft, start a small fissure, and then press vibration finally severs the shaft. It is a most distressing accident when a high-speed flywheel suddenly breaks away and then crashes every object it meets during its wild bouncing trip across a pressroom floor.

When press speeds are greater than those recommended by the press manufacturer, the chances that this accident will happen are about once every ten years where 30 presses are running 8 to 10 hr. daily. But if one or two men are seriously injured or killed, and $1,000 worth of property is destroyed, one such catastrophe is "plenty" to happen after any length of time.

Catching Flywheels "on the Fly."—A structural steel frame and two jaws are forged to the indicated shapes seen in Fig. 305. Two angularly positioned braces are welded, one on each side of the frame, as illustrated. This assembly is then mounted across the top of the press frame and secured with nuts on the upper ends of the threaded tie rods. The two jaws are detachable, and outside jaw *A* is bolted to the frame last.

This safety device has been tested on a No. 4 press where the flywheel weighed 950 lb. and was revolving 100 r.p.m. To make the test, a discarded crankshaft was sawed nearly through next to the flywheel. The jaws safely caught the wheel when it fell, and, while the safety frame was somewhat distorted, the wheel remained within the jaws after coming to rest.

Flywheel Spokes.—Instead of having spokes within flywheel rims, there should be a solid web. This is the case in most types of modern power presses, and it is a well-chosen feature of safety. However, most "old-timer" machines have "spoked" wheels, and such wheels in motion are a hazard to the safety of operators. The spokes should be covered with a thin sheet-iron disk, or even plywood can be used if metal cannot be obtained. In addition, state laws require that all exposed wheels and belts in the shop be enclosed in metal guards.

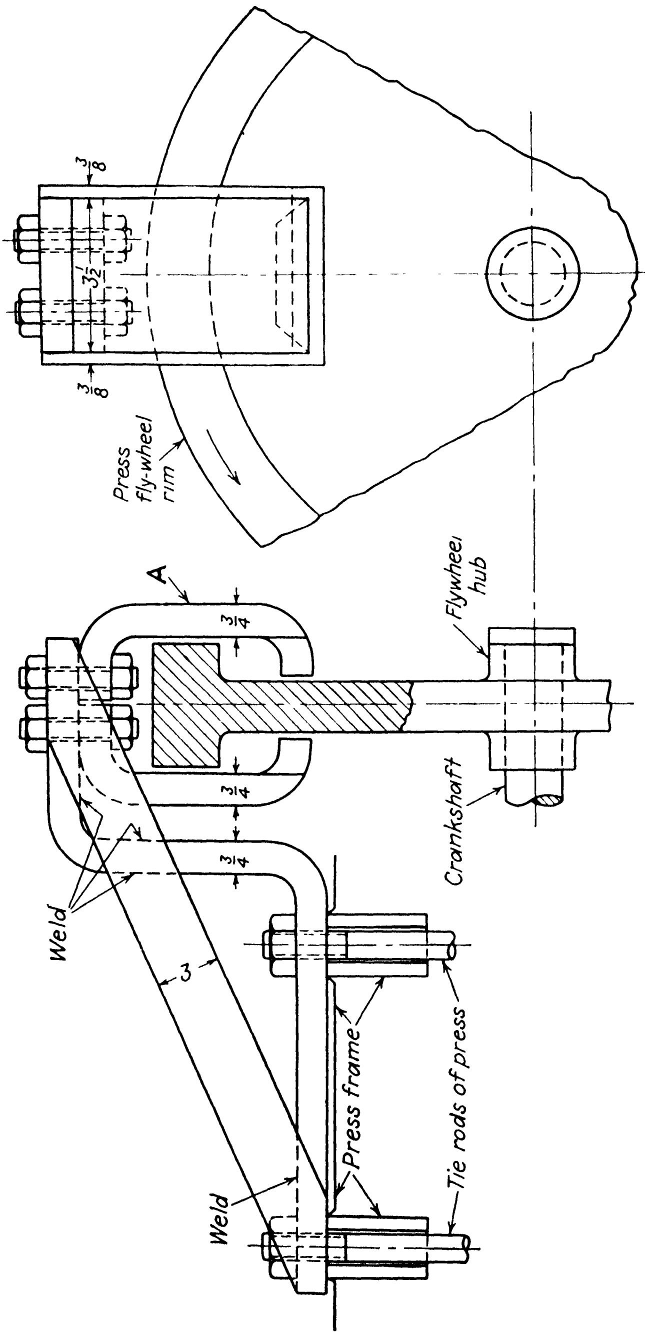


FIG. 305.—A successful safety appliance for power presses are these substantial welded frame and jaws that catch falling flywheels if the crankshaft breaks.

Safety of Die Setters Jeopardized.—A die setter should never attempt to adjust press-ram heights while the flywheel is in motion. Experienced die men know this and avoid doing it. Some crankshafts are provided with a hole through their left ends. A die setter uses a round bar through the hole as leverage for slowly lowering the ram in order to adjust its height. If the flywheel is in motion, and the clutch mechanism is defective, the clutch may suddenly engage, whereupon the bar is yanked out of hand, injuring the man severely. Skulls have been fractured by neglecting these simple precautions.

Safety of Die Setters Established.—To eliminate these dangers, if the press is driven by a pulley on a common shaft with other pulleys and presses, the belt should always be removed and the flywheel turned by hand. If the press has an individual motor drive, it is best to throw off the belt, but if there is a *V* belt drive, the motor switch should be turned off. In some shops, the die setter is provided with an adjusting bar having a "hooked end." A pin driven through the hole in the left end of the crankshaft projects about 1 in. on each side of the shaft. The hook on the bar is engaged over the pin for leverage when moving the ram. With this equipment, the die setter is protected from injury even though the flywheel is in motion and the clutch accidentally engages.

A power press is a dangerous machine in the hands of inexperienced help. Questionable jokes and "horseplay" attempted in connection with such machines have no part in today's serious programs.

Safety Power Presses.—This press has a transparent guard or curtain of white sheet celluloid, or Cellophane, around the danger zone in front of the die. Rods attached to the guard frame connect with the clutch-operating mechanism in such a way that the press cannot be operated until the guard is down. It is also impossible for the guard to rise until after the press stroke has been completed.

If the operator inadvertently places his fingers or hand under the guard, or if there is any other obstruction present, the press ram cannot be caused to function, or the clutch to operate. The guard is actuated by such a light stretch of coiled tension springs that the operator's hand will not be injured even though the guard comes down on his hand.

This safety device has prevented many serious casualties, and its use does not interfere with the output of the press because it does not hamper the vision or movement of the operator. It is excellent protection when attached on small presses used by women operators (see Plate XI, page 415).

Other Safety Devices.—In regard to using any safety appliances on presses, it is well to remember that a small bench press will crush

fingers just as easily as a large press will. A small press may be even more dangerous, because it operates faster. It is best to install some kind of automatic feed or to encase the punch in glass, or Cellophane, or a net with a lamp inside shining on the die but shielded from the operator's eyes. A little hand slide should be made and attached on the die to feed the parts under the punch.

In bending, forming, and assembling dies—if the work clings to the punch—arrange a side cam, latches, or hooks that will eject the piece automatically when the ram ascends. This relieves the operator from attempting to remove the work by hand—always a very dangerous procedure.

If a tool can be so designed as to give the operator a sense of safety, it improves his morale and operating conditions and increases output. Recently, several new safety devices have appeared in which the operator's wrists are attached to pull-back belts. The belts are arranged in connection with the clutch so that hands are pulled away from the danger zone under the punches the instant the clutch engages. These safety measures seem to promise more security for the operator, although they occupy considerable space in front of the press. Practically all the safety devices used in the past can be made inactive by a dishonest operator who tries to "beat the rate"; or else they tend to retard fast work, and the output falls (see Plate XIV, page 420).

Photoelectric Safety Equipment.—Among the best safety appliances are the photoelectric-cell devices, but some press operators are skeptical about these because they seem so intangible. The main objections to them are their tendency to cause the press to become inactive sometimes when no danger of an accident is present, and their high cost of installation, adjustment, and upkeep. A mechanical safety mechanism is probably best for the operator's protection, because he naturally wishes to see and understand why the press will not operate when an injury may occur. In the case of the photoelectric-cell devices this visual satisfaction cannot be had.

But aside from all this, safety devices either do not fully protect, or they slow down production. So, for maximum safety, especially for women operators, an automatic feed of some sort is necessary, or the encasement of the die in glass or a screen is advocated.

Accident Causes in the Pressroom*

1. Repeating press, caused by broken clutch or latch spring, flywheel freezing on shaft or operator riding on trip treadle with foot.

* R. A. Shaw, safety director, The Murray Corp. of America.

2. Adjusting screw or ram breaking, loose or oily brake allowing ram to drop back or forward.

3. Uncovered foot treadles—exposed to falling tools, etc.

4. Operation of a press or safety device needing repairs.

5. Failure to use properly the safety devices that are provided.

6. Operator getting out of time with press and beating the ram on downward strokes.

7. Greasy dies, loose or worn bolts, nuts, or screws, ill-fitting wrenches, wrist-length sleeves.

8. Failure to clear press bed and die of wrenehes, clamps, bolts, etc., before starting work.

9. Carelessness in parking dies around press or failure to use lifting eyes when handling heavy dies.

10. Careless and indifferent stacking of finished work, improper placing of material and tote pans about presses.

11. Handling of thin sheets, scrap, or remnants without hand leathers or forks.

12. Attention of operator being drawn from his work by other employees.

13. Failure to use goggles where there is a possibility of flying particles.

14. Lack of competent and frequent inspection of all presses and equipment.

15. Failure to instruct the new press operator properly.

MECHANISM FOR OPERATING AUTOMATIC HOISTING AND STACKING TONGS

The problem of providing more floor space to meet the requirements of companies engaged in armament work has been solved in some cases by placing manufactured parts and partial assemblies into labeled barrels, boxes, or drums, and then piling up these packed containers to a height of several tiers. While this has been found a satisfactory method of obtaining extra floor space, it requires the use of a crane and good material-handling equipment. The quick-action automatic tongs here illustrated, with operating mechanism designed as shown, were constructed especially for use in performing this work.

Referring to Fig. 306, center bar *A* and latches *B* are flame-cut from rough structural steel 3/4 in. thick. The center bar is purposely made heavy, so that it will descend by gravity when released. The four bars *H* are welded to the sides of the pivot bars, and the two lower crossbars *C* are welded across the lower ends of bars *H*, as shown in the upper right-hand corner. The toothed gripping jaws *D*, four in

number, are designed to obtain an equalizing grip on the container to be lifted. This feature permits the jaws to clamp and lift either round barrels, or containers or boxes having flat sides.

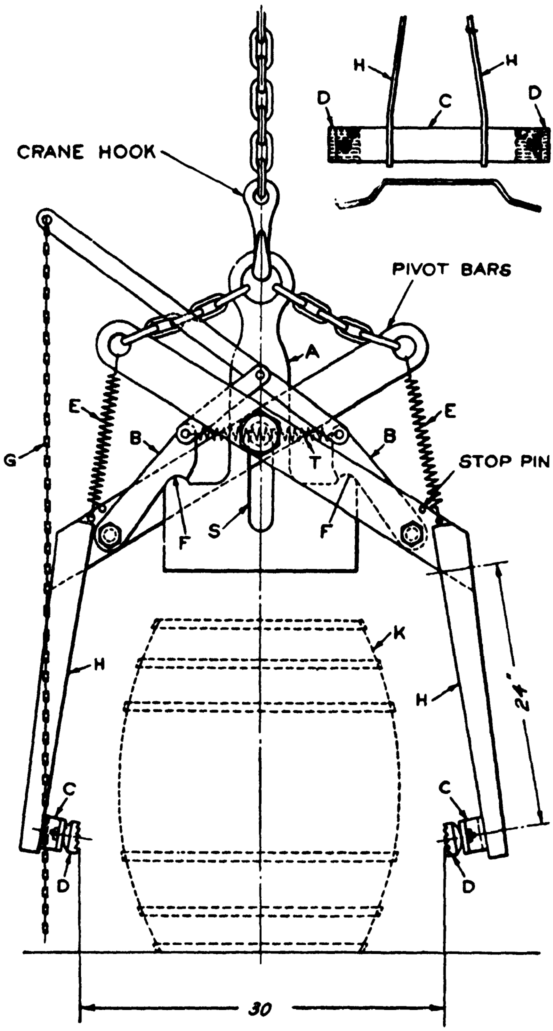


FIG. 306.—Hoisting-and-stacking tongs with mechanism for gripping a barrel or box when control chain G is pulled and for releasing the load automatically when the crane hook is lowered and hoisted.

When the tongs are open, latches B are hooked over the two arc-shaped sections F that form part of center bar A. The tongs are then placed around the object to be lifted. A slight pull of the hand on chain G opens the latches and frees bars H and jaws D, so that they

approach each other and firmly grip any object to be handled, such as barrel *K*. The load is then hoisted by the crane hook and placed in the desired location.

When the crane hook is lowered, the center bar descends by gravity, as provided for by the vertical clearance slot *S* cut through its center. When it has descended far enough, latch hooks *B* are caused to snap together over the arc-shaped sections *F* through the pulling action of spring *T* attached to their ends. When the crane hook is again raised, the latches cause the jaws to open so that the tongs are ready to be lowered for lifting the next container.

In removing packages from the tops of the stacked tiers, the operation of the device is simply reversed. The two light-tension springs *E* serve to prevent the jaws from collapsing or coming entirely together.

In building this equipment, no precision fits are necessary. The center block has a clearance of about ⅛ in. between the pivot bars. A separator bushing through the long vertical slot and around the pivot bolt has a similar clearance. These tongs grip securely anything that can be placed between them. Although the distance between the open jaws *D* is indicated as 30 in. in the illustration, this opening can be adjusted by providing several holes for the latch fulcrum bolts at different positions.

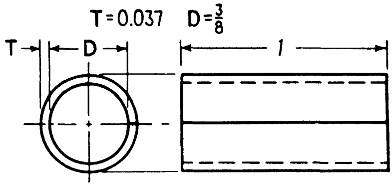


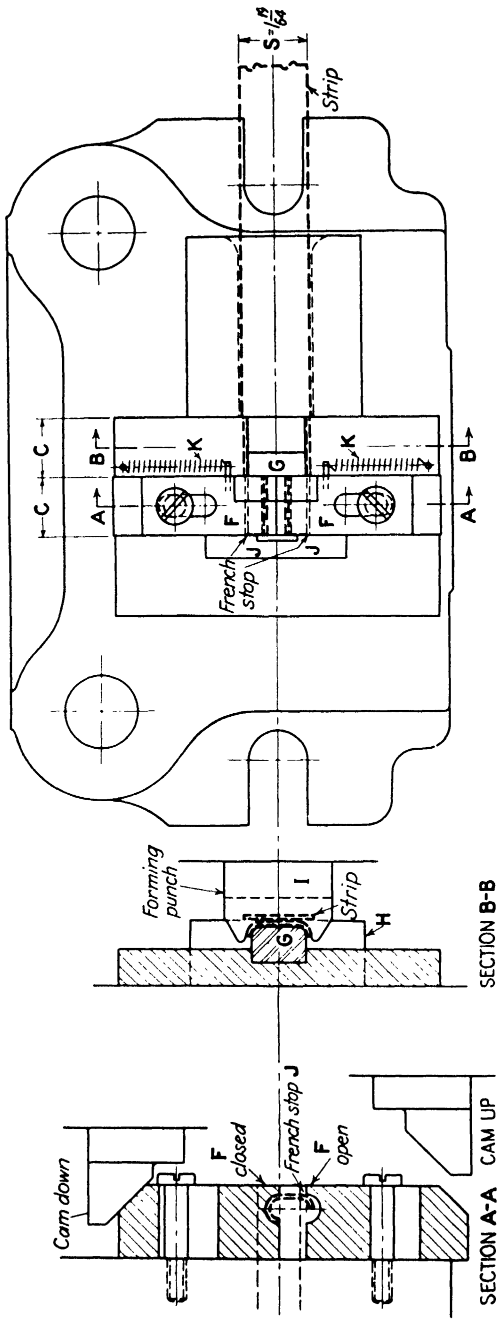
FIG. 307.—A spacer-tube-separator sleeve that is to be rapidly produced in large quantities.

125 Spacer Tubes per Minute.—This high-speed die is a useful design for manufacturing many sizes of sheared and curled tubes for separators, rollers, sleeves, key locks, etc. Figure 307 shows the work to be produced. The developed width of strip *S* for the die in Fig. 308 is determined by the following formula: $S = \pi(D + T)$. In this case, $S = 3.1416 \times (0.375 + 0.037) = 1.294$, or $1\frac{19}{64}$ in. The pounds of material *P* required per 1,000 pieces is

$$P = S \times C \times W \times 7.3,$$

in which *W* is the material weight in pounds per square foot and *C* the length of the tube. This formula provides 5 per cent for waste ends and misformed pieces.

Shearing and Forming at Station 1.—In operation, the strip is entered at the right end of the die under the stripper channel *E*. It is then advanced until its forward end registers against the right sides of



S = 1 19/64
Strip
C
C
B
B
K
K
G
A
A
F
F
J
J
French stop
Forming punch
I
Strip
G
H
SECTION B-B
Cam down
F closed
French stop J
F open
SECTION A-A
CAM UP

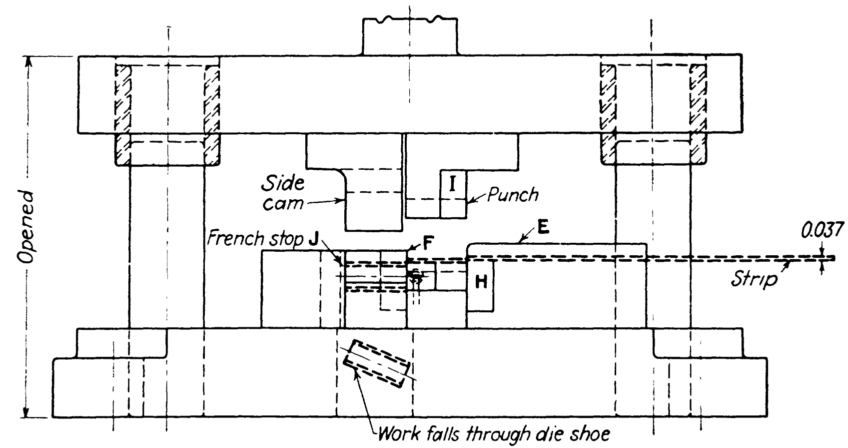


Fig. 308.—High-production two-step shearing and forming die for producing the steel spacer tube sketched in the preceding figure. The approximate output of this tool is 7,500 pieces per hour.

the two forming blocks *F*. When the ram descends, one-quarter of the tube circle is formed down at each edge of the strip, as seen in section *B-B*. Forming block *G* is $\frac{1}{64}$ in. shorter than the height of die block *H*, so that punch *I* not only forms down the quarter bends, but it also shears through the bends and starts a shallow cut across the entire width of strip.

"French" Automatic Stop.—In the next move forward of the strip, the formed-down U-shape end of the work registers against the "French" stop *J*, as indicated in section *A-A*. On the next descent of the ram, the shearing and forming operation at *G* is repeated, and two side cams, in descent, close slides *F* together. The formed ends are then curled toward one another in semicircles, thus completing the tube. Half of the completed tube is shown in the closed slide *F*, in section *A-A*.

Shearing and Forming at Station 2.—The semicircular openings in slides *F* for curling are $\frac{1}{64}$ in. lower than the top of block *G*, and for this reason the piece is sheared from the strip while being curled and formed. It will be recalled that this shearing cut was started in the station 1. When the ram ascends, the slides are opened by the coiled tension springs *K*, and the work falls into a hole through the die shoe and bolster plate, and then out beneath the press.

Grinding.—Removable blocks are provided on the faces of *F*, *G*, *H*, and *I*, as shown. These blocks are ground on their vertical faces and then "shimmed" out to maintain the correct cut length of the work. However, it is seldom necessary to grind block *G*, as it is a simple piece and performs only a light cut on its left edge. This being so, it is usually best to replace *G* with a new block instead of attempting to grind and "shim" it out.

Lifting Blanks with Vacuum Tips.—In stamping operations or in performing light press-tool assembling operations, the punch holder can be provided with a soft-rubber vacuum tip, mounted on the end of a stud of sufficient length to allow the tip to make contact with some part of the work when the ram is at the bottom of its stroke. As the ram ascends, the blank is lifted from the die, adhering to the vacuum tip until stripped from it by "sky hooks" or, if possible, by a positive knockout rod through the shank of the punch.

If the press is inclined, the work is automatically delivered at the rear of the machine. This simple convenience is positive and sure, and greatly increases the output per hour as compared with removing the work by hand. When these tips are used in connection with a horizontal machine, the possibility of serious accidents is lessened considerably.

The rubber vacuum tip is secured to the stud by a flat-headed screw which passes through the center of the tip. If the work is heavy, two or more larger tips may be used in conjunction.

A comparatively recent development for lifting large stampings above the strip, to prevent interference when the coil cradle feeds the sheet ahead, operates as follows. Soft-rubber vacuum tips are attached on studs from the press ram and on the downstroke engage the blank by suction. Each of the tips has a hose connection leading to a vacuum pump atop the press. When the ram ascends, the tips lift the work, leaving the die open for feeding. At the top of the stroke the vacuum is automatically released, and the stamping drops down for hand removal. This installation is used in blanking front fenders for automobiles and for other large work.

New Uses for Silver.—Revolutionary discoveries about the industrial uses of silver have recently been made, and from these discoveries America will forge a larger and better war machine. The United States practically has a "corner" on the world's silver supply and is in a position to make the most of it.

Silver has the highest electrical conductivity of all metals. It is an excellent substitute for copper, zinc, tin, and nickel. These metals can be released for other useful purposes by substituting silver. Silver and its alloys are now employed in the construction of battleships, bombs, guns, shells, tanks, torpedos, trucks, and planes. Airplane connecting-rod bearings are coated with silver to facilitate lubrication and to reduce shock and vibration.

Copper plates and heavy parts used in electrical machinery, bus bars, switches, conductors, and connectors can be removed and replaced with silver, but when copper becomes plentiful it is put back on the machines, and the silver is recast into its original bars with small loss.*

The chief industrial use of silver at present is silver solder. This solder will join metals so firmly that the joint is actually stronger than the original piece. The use of silver bearings in American bombers and fighting planes increases their speed and enables their engines to withstand greater shocks and vibration. In general, silver adds greatly

* A statement prepared by the Office of War Information in Cleveland, Ohio, says that during the first 6 months of substitution of government silver for copper bus bars over 15,000 tons of copper was released for other uses in the war. By the end of 1942 more than 20,000 tons of copper had been released, and by 1943 silver in the amount of 43,000 tons will be conducting electricity in the manufacture of aluminum, and a similar weight of copper will have been released. After the war the silver bars will be restored to the government vaults unharmed, and copper again will be used for bus bars.

to the life of all types of engines. In the case of breakdowns, repairs which might otherwise take several weeks can be made in a few hours with silver solder. The pressworking and drawing qualities of silver even exceed those of copper, and in drawing qualities copper is best among ordinary metals. The specific gravity of cast-hammered silver is 10.7, and its weight per cubic inch is 0.389 lb.

Heading Cartridge Cases Hydraulically.—Here in Fig. 309 is a picture of a 2,000-ton hydraulic press for heading anti-aircraft cartridge cases in a fully automatic, two-position, dial-fed die. The die is provided with an ejector sliding mechanism.

The press is of four-piece frame construction with side housings "keyed" to the crown. The tie rods are preheated and shrunk in place, giving the frame a preloaded condition. The main drive is operated by a 75-hp. motor, and a 7½-hp. motor drives the ejector, which develops 38 tons capacity. There is also a two-station dial or die which is rotated pneumatically. The dial is equipped with hydraulic dash pots to eliminate shock from impact when stopping.

After the dies are loaded with the cartridge cases to be headed, by using the starter button, the lower dial is caused to rotate 180 deg., which moves a new case under the press and shifts the previous one out of the press and over the ejector position. When the dial and work are in the new position, the punch immediately descends at high speed but is slowed to pressing speed just before contacting the work; impact injury on the tool members is thus avoided. The punch then continues at pressing speed until it attains a predetermined pressure, which can be chosen from a wide range. When the punch descends to its predetermined pressure, it automatically reverses and returns to its normal starting position.

If two pressings per case are desired, the punch shifter automatically moves into second position and the out-pressing operation is repeated, with independent pressage control. However, during the first pressing, the ejector raises the other completed case out of the die and the operator picks it up with the air hoist, which is designed for lifting finished cases clear of the die.

On the second pressing, the ejector recedes. This feature provides for loading time and also for lubricating the die between operations.

Safety interlocks are provided to ensure that the punch and die are properly aligned and to prevent operating the press unless work has been placed in the die. A production of 300 anti-aircraft cartridges per hour can be headed, each case being pressed twice.

Surface Broaching.—Figure 310 shows the principal working parts of a large hydraulic broaching machine. Notice that widths of the

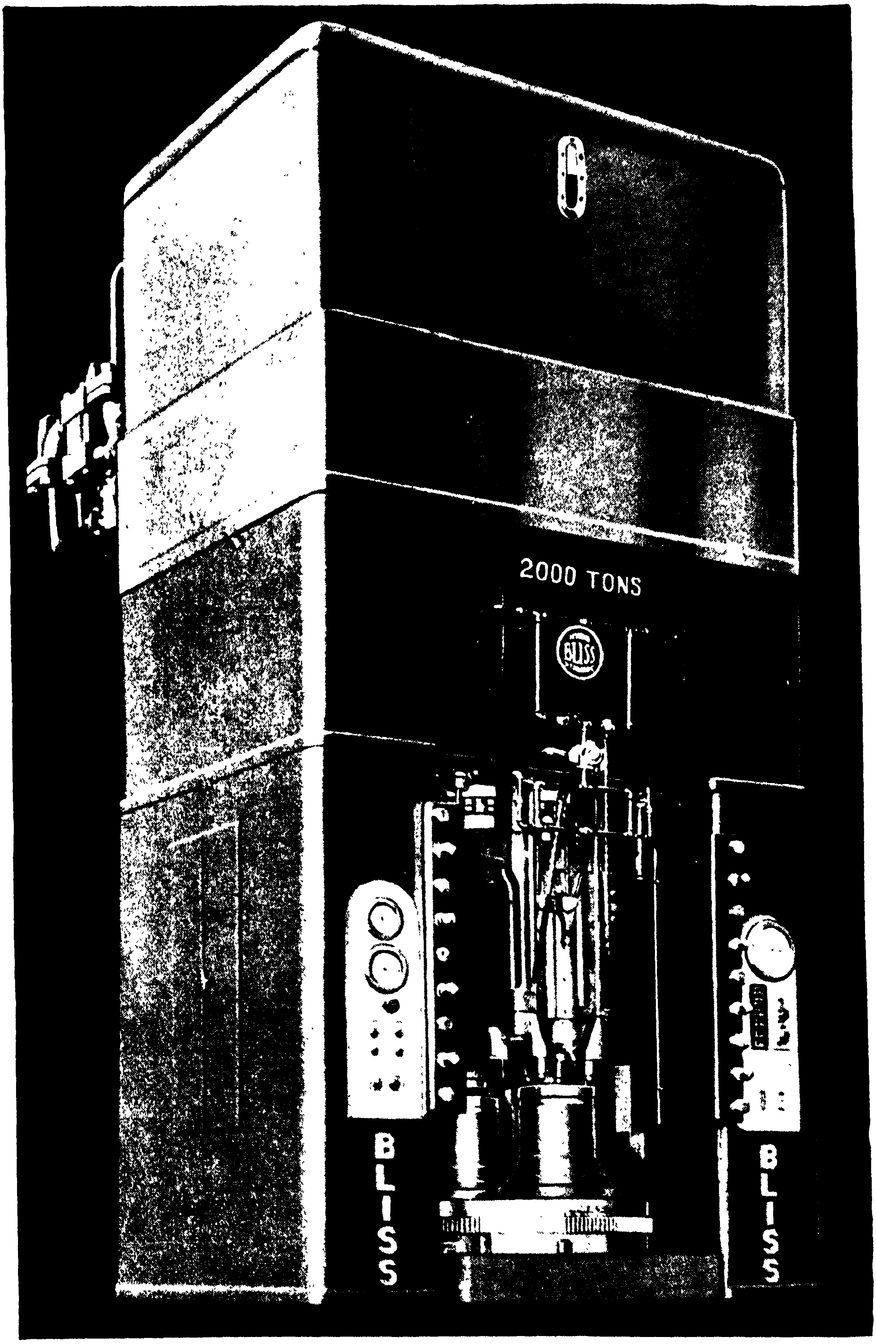


FIG. 309.—A two-position die setup in a 2,000-ton hydraulic press for heading cartridge-shell cases.

dual-ram slides are designed for mounting wide broach bars so that surfaces on quite large pieces of work can be broach-finished.

The finished pad shown across the front of the table, where the name plate is seen, is for the purpose of attaching brackets to secure fixture clamps that hold the work during broaching. A knee bar, shown just under the pad, extends the full length of the machine. The operator simply leans against this bar to stop the machine.

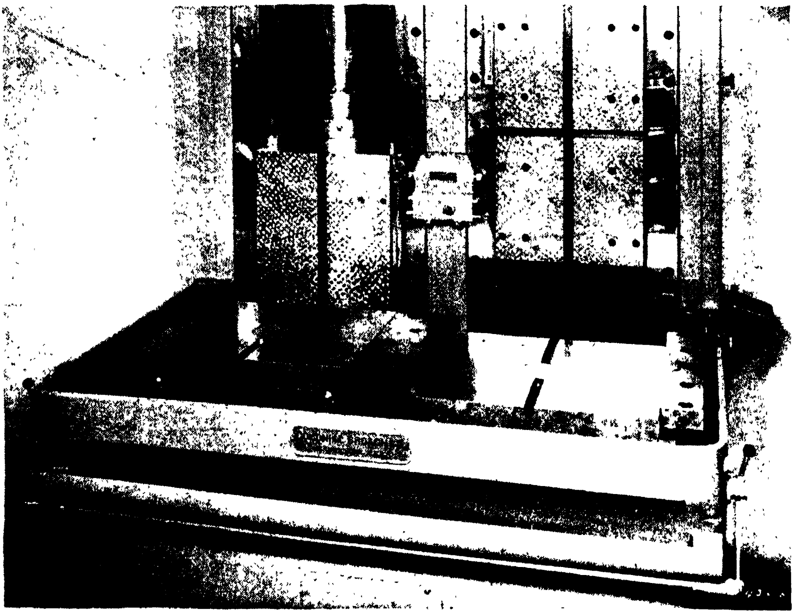


Fig. 310.—Close-up view showing the dual rams and receding tables of a modern broaching machine. Broaching operations are several times faster and therefore more economical than milling operations. (*Courtesy of Colonial Broach Co.*)

Figure 311 shows the principle of operation used in these broaching machines; that is, one ram is up while the other one is down, and vice versa. Using two rams makes it possible to broach two different operations on the same piece of work simultaneously, or one operation on each of two different pieces. The workpieces in connection with this figure are the front steering knuckles for automobiles. Piping shown across the front of the machine distributes the cutting compound, which is delivered at the operations. The hydraulic cylinders, motors, and pumps are contained within the housing of the machine.

Broaching on Punch Presses.—In general, broaching dies are used for cutting shapes in light and medium heavy parts; but there is no good reason why they cannot be employed for heavy operations, given the correct punch speed and the necessary travel of the press slide.

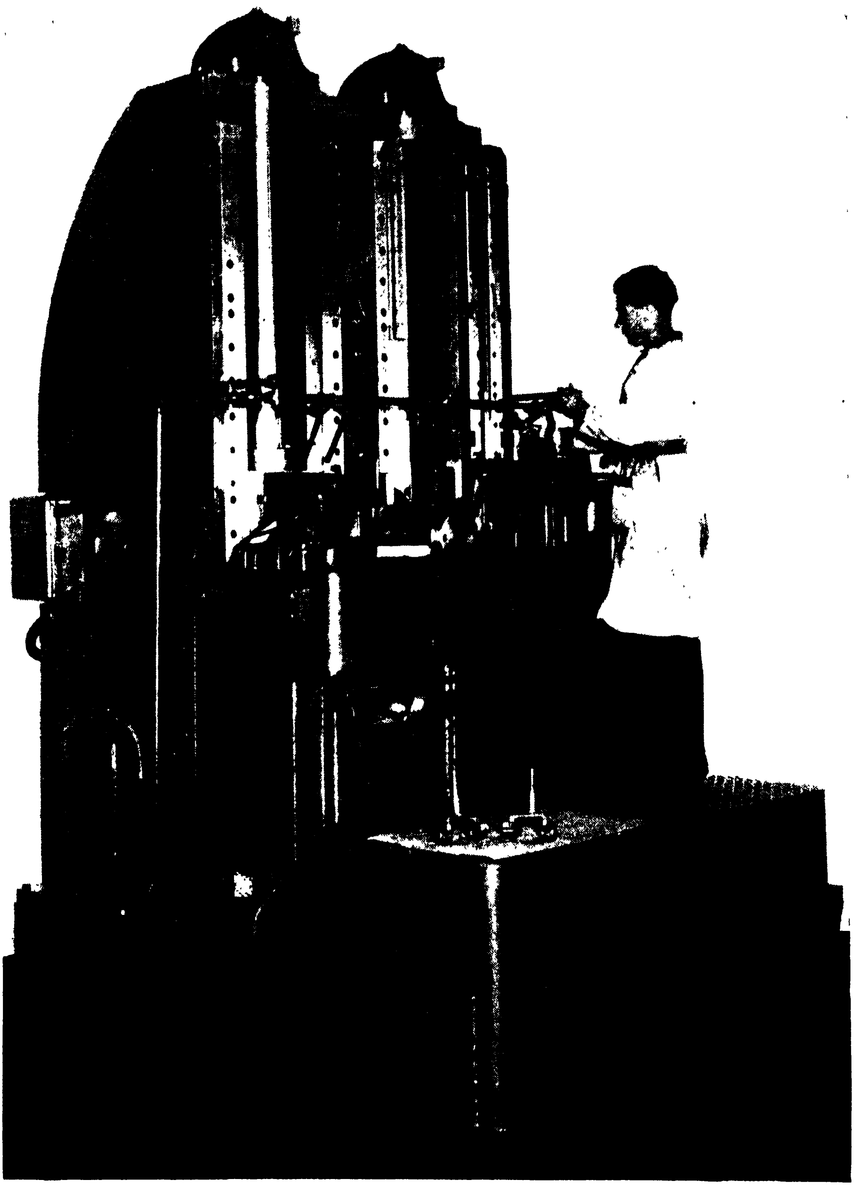


FIG. 311.—Broaching steering knuckles for motor vehicles. One ram broaches the inside and outside of bosses on the knuckle while the other ram broaches the ears on another knuckle. Samples of the work are lying on the platform beside the operator. (*Courtesy of Colonial Broach Co.*)

Ordinary punch presses usually have too short strokes for very deep broaching cuts, hence it became necessary to design special broaching machines. Deep broaching operations, in quantity production and for parts too large to be handled in punch presses, are fabricated in horizontal broaching machines, in which a long broaching cutter is ordinarily pulled through the work (see Fig. 318).

Broaching dies are particularly useful in operations on thick blanks, for internal cuts through forgings and castings, and for external cuts in either the sides or at the ends of commercial sections. Internal broaching is used for enlarging round holes or for changing round holes to other shapes.

In broaching dies, the workpiece must be rigidly clamped in opposition to the cut, and all the working members of the die, especially the broaching punches, must be of sturdy design and construction. The broaches should be well supported and guided in order to resist excessive wear and breakage. The die set should have precision-fitted guideposts of comparatively large diameters; a "staggered-post" type of die set equipped for broaching in a straight-side press is the ideal setup.

Broaching cuts are governed by the same restrictions as are found in all other machine cutting operations, namely, to attain the maximum speed of the cutting tool, in feet per minute, without its showing excessive wear or failure; the disposal of chips; use of proper lubrication; the effect of certain tooth shapes; and the maximum feeding distance into the work that the teeth can safely take at each cut.

For certain external cuts, broaching is considerably faster and less expensive than milling. For example, it is a simple operation to broach several straddle cuts in a single-operation die, on the opposite edges of work and at given distances from the ends of long pieces. To mill the same cuts, several operations would be necessary unless an expensive and complicated fixture is used.

An example of internal broaching is in cutting a keyway along a finished hole through a hub. The broach, in descent, "pilots" through the hole in the hub, and the teeth do not begin to cut until the pilot end has fully entered a fixed guide bushing beneath the work. A clearance slot is provided within the wall of the bushing coincident with the line of the broaching tooth travel.

For external cuts, broaches are designed with comparatively heavy backing heels. The heels are supported and guided on three sides by long slots cut in guiding blocks which are rigidly attached to the surface of the die or shoe. Guiding slots are lined with hardened, ground, and lapped plates to ensure long wear. The guides are attached

opposite the cuts. Guiding should start above the cut and continue below the surface of the die shoe and beyond if necessary. Only the cutting edge of the broach is exposed, plus a small clearance, which together provide sufficient depth to suit the operation (see Fig. 317).

The cutting principle governing the operation of broaching punches, the tooth shape, and the chip clearance is closely related to that of formed milling cutters. The travel of a broaching punch should not exceed 40 ft. per minute in ferrous metals. An emulsion cutting compound is used for steel forgings and cast iron to obtain free cuts and smooth finishes. Some grades of steel forgings may require a lubricant of animal oil for heavy cuts. Brass can be cut up to 80 ft. per minute, or higher, for light operations of regular contours. Cutting speeds employed in hydraulically driven broaching machines seldom exceed 40 ft. per minute.

These data indicate that a power press, which has been speeded for ordinary piercing and blanking dies, has a slide travel that is about right for broaching. A press slide that runs at 120 strokes per minute and is driven by a 1½-in. crank throw has an average descent of 30 ft. per minute. For presses that run at higher speeds it is advisable to reduce the number of strokes per minute for heavy broaching operations.

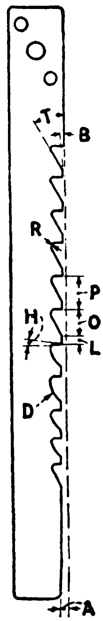


FIG. 312. When designing broaching teeth, it is best to arrange the first three or four starting teeth, at the small end of the bar, closer together than the normal pitch P, so that in operation they will lead the succeeding teeth into the cut.

Designing the Teeth.—The usual shapes for broaching teeth are shown in Fig. 312. The pitch P, or the distance from tooth to tooth, is determined by the formula $0.35\sqrt{C}$, in which C is the length of the cut. However, it is best to decrease the constant 0.35 to 0.20 when cutting distances are less than ½ in., so that two or more teeth will be cutting at the same time.

The "land" L, which is about ⅕ P, is slightly "backed off" as indicated by angle B; this angle may vary from zero to ¼ deg. The pitch can be decreased to suit unusually hard or difficult work or for abnormally long and wide cuts. The tooth angle T, which is normally 30 deg., is sometimes decreased to avoid weakening the cross section in very small broaches.

Fillet R, at the root of the teeth, is made as large as chip space will permit. Chip clearance may be increased by using an arc connection as shown at D, instead of a straight-line connection between the teeth. The last three or four teeth at the top are straight in line for accurate

finishing of the cut. A rake angle H, of 5 to 7 deg., can be specified in all the teeth; this design favors curling the chip and tends to decrease the pressure required to operate the broach.

The feed from tooth to tooth is determined by the cutting resistance of the work material, as it is for cuts in other power-driven machines. It depends largely on the hardness or toughness of the material and the quality of finish desired. The feed is controlled by the acuteness of angle A; this angle can be slightly altered, if necessary; after the broach has been hardened, the angle can be changed by grinding. Tooth opening O is approximately equal to depth of the tooth/tan T, and the feed per tooth is equal to tan $A \times P$.

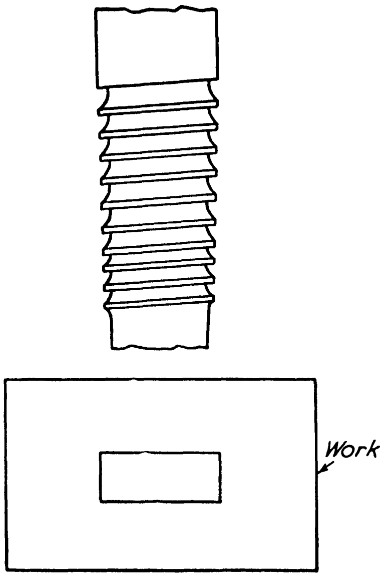


FIG. 313.—Teeth on a broach for enlarging square or rectangular holes should be slanted in opposite directions on reverse sides of the tool to provide balanced shearing cuts, which tend to prevent side thrusts.

Press Broaching Large Holes.—Broaching bars of this type are usually pushed entirely through the work and die holder and then returned by hand for making the next cut. A broaching tool is simply an increasing series in sizes of shaving punches, one placed above the other. This comparison reveals the surprising similarity in different kinds of cutting operations. The design of a large broach is shown in Fig. 313.

Scope of Broaching Operations. The variety of shapes that can be broached is limited only by the skill of the designer and toolmaker in producing a tool blank of the proper length, taper, and cross section and in providing it with the most efficient number and shapes of teeth and lastly by the ingenuity of the tool hardener. A broach that has warped in hardening can sometimes be straightened while the temper is being drawn.

Broaches are used for such common internal shapes as: round, oval, square, rectangular, regular or irregular polygons, and combinations of these shapes. They are also used for many variations of cuts for splines. Keyways and small internal gears are well-known examples of internal broaching. Internal helical grooves can also be broached by causing the broach to revolve while following through the lead of a long spiral. Broaching is a "follow-up" cut; it is a cut

easily controlled by the length of the broach, by the depth of the feed per tooth and by the number and shapes of teeth. It is possible to broach a large variety of external contours for small slots such as half-hexagonal and U-sections; this can be done on a production basis more rapidly in a die than by milling with a profiling cutter Pads and bosses on castings and forgings can also be broach finished on a high-production basis. Special broaching machines are commercially built for this purpose. (See Fig. 310.)

A fixture similar to one for milling is made to hold the parts and to support the surfaces to be broached, near the cuts. In modern broaching machines, the cutters are attached on vertical holders, operated

FIG. 314.—Typical link in a crawler-type tractor or tank chain, showing broached cuts that cross the link and straddle the two holes. (*Courtesy of Colonial Broach Co.*)

hydraulically. Many small parts of army rifles, such as trigger guards and triggers, rifle bolts, and the front locking lug, are broached, internally or externally as required, at production rates of 200 to 800 pieces per hour. Automotive steering knuckles are also broached on several surfaces simultaneously. (See Fig. 311.) Broaching is rapidly replacing milling in light manufactured parts. It is much faster than milling and makes smoother cuts without leaving revolution marks. A vertical broaching machine is simply another type of metal-working press.

Broaching Tank and Tractor Links.—Increased production with greater accuracy is now being attained by broaching all machined surfaces and holes in the crawler-type track links used in various types of tractors, tanks, etc. Since nearly 500 of these links are

required per complete assembly, depending upon the over-all length of the track, an increase in the output of complete units using tracks of this type calls for greatly increased productive capacity. If the production method can be improved the cutting time per piece will be materially decreased.

As shown in Fig. 314, the flats on each side of the holes are broached. The holes must be accurately spaced to maintain the desired over-all

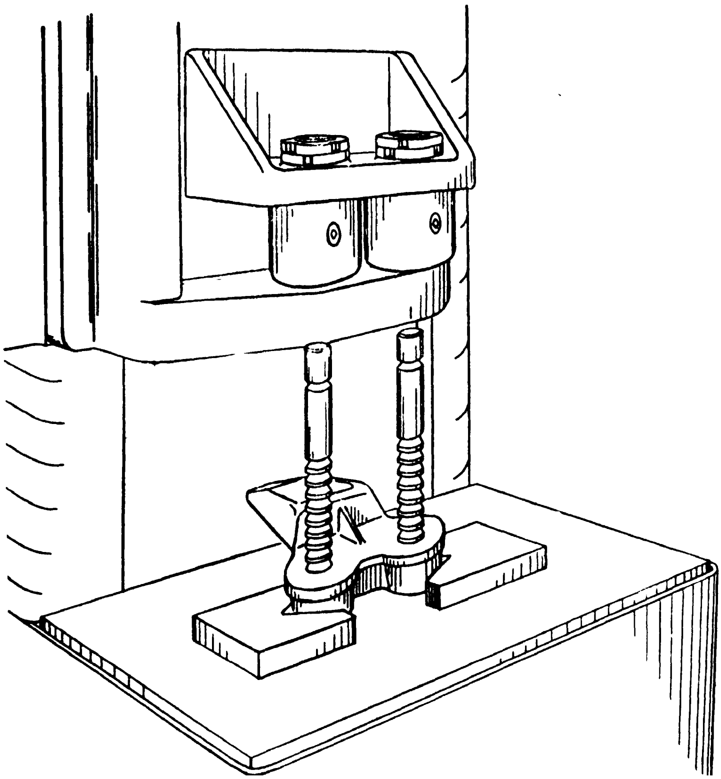


FIG. 315.—Indicated setup for holding and accurately broaching the two holes in a crawler-type tank-chain link. (*Courtesy of Colonial Broach Co.*)

length of the assembled track. Finishing the holes to close limits is also essential to obtain proper fit of the link pins. Formerly the holes were drilled and reamed and the flats were milled. By surface-broaching both flats simultaneously production time was further reduced. Similarly, the adoption of broaching for finishing the holes saved valuable equipment and time for other purposes. Figure 315 shows the part after surface broaching and ready to finish broaching the holes.

Types of Broaching Machines.—The three drawings Figs. 316, 317, and 318, are used by the courtesy of Illinois Tool Works. These

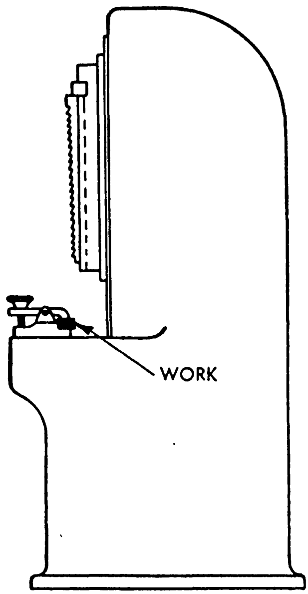


Fig. 316.—Outlines of a vertical surface-broaching machine in which the tool holder is backed up by the body housing of the machine when long heavy cuts are taken.

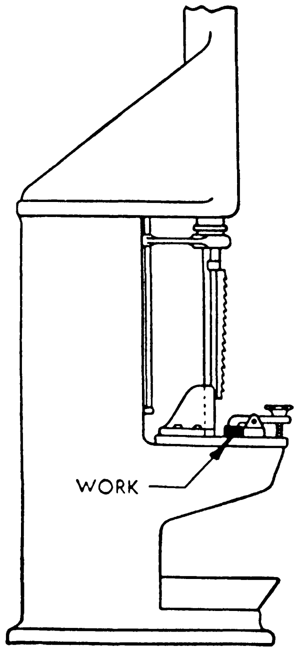


Fig. 317.—Push-type vertical broaching machine adapted for cutting light surfacing operations in which the tool holder is backed up by the bracket shown attached on the table of the machine.

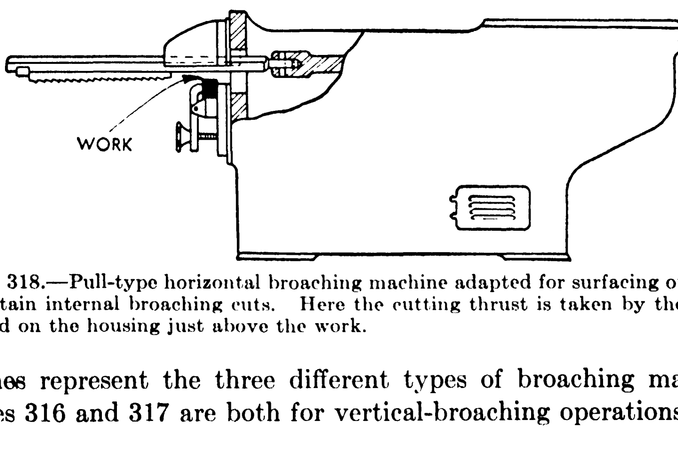


Fig. 318.—Pull-type horizontal broaching machine adapted for surfacing operations and certain internal broaching cuts. Here the cutting thrust is taken by the bracket attached on the housing just above the work.

sketches represent the three different types of broaching machines. Figures 316 and 317 are both for vertical-broaching operations. The

vertical machines are classified in three types: the pull-up, the pull-down, and the vertical-press and ram surface-broaching machines.

The pull-up types are used primarily for internal-broaching operations, such as rounds, splines, squares, or gear teeth. Such machines are usually equipped with automatic broach-handling mechanisms, which make it unnecessary for the operator to return the broaches by hand. This is especially advantageous when using extremely large and heavy broaching tools.

It is also good practice to provide an extra long rear pilot guided in a bushing long enough to permit the work to seat itself before the pilot is released from the guide bushing. This arrangement prevents the broach from "drifting," and thus produces a hole that is square with the face of the work. In spline broaching, drifting is largely overcome by seating the work to a depth of about $\frac{1}{32}$ in., or more.

The horizontal types, Fig. 318, are primarily used for broaching round holes, keyways, and splines, but are also used extensively for surface-broaching operations when provided with proper tooling and conditions in connection with the fixtures.

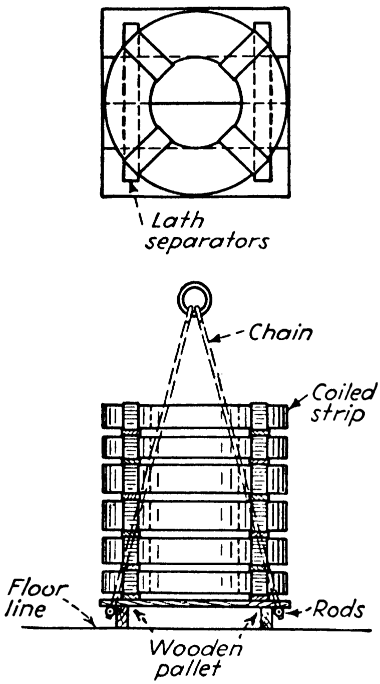
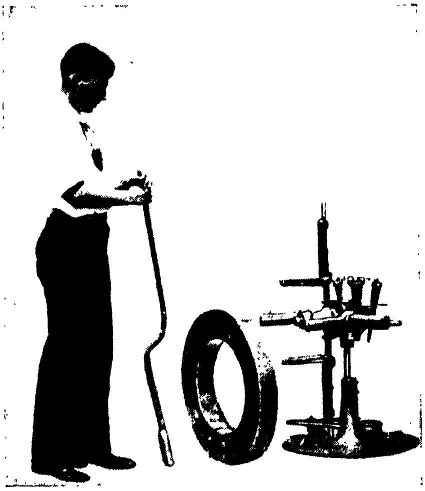


FIG. 319.—A wooden pallet loaded with coil stock and lifted by a chain sling attached to a crane hook is a good way to lift, transport, stack, and unstack heavy coils of metal strip.

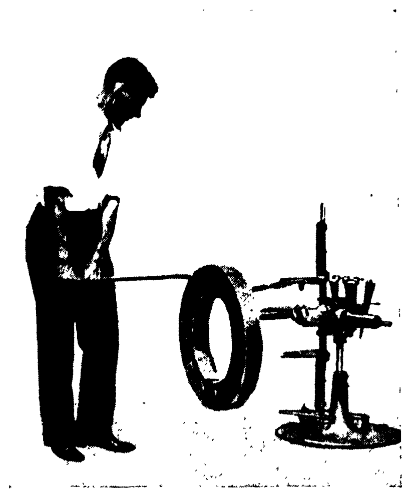
Transporting Coiled Strip Stock.—Coils are usually shipped from the mill and handled in the pressroom, laid horizontally on strong wooden pallets, as illustrated in Fig. 319. A chain sling is spread under the pallet ends, and the load is hoisted after attaching the chain to an overhead crane. Each load may weigh from 1 to 3 tons.

The pallets and coils are hoisted from the stocking section and brought into line with one of several terminals in a monorail system that leads to the various presses. After the load is attached to the trolley on a monorail, it can be weighed, if necessary, on a scale section in the track, or rolled on to a freight-elevator track for distribution on other floors. The load is lowered at the press, either on the platform of a portable elevator truck placed under it or by using a collapsible

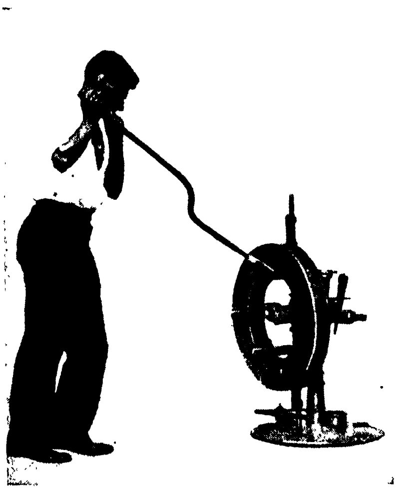
truck. If a monorail system is too expensive to install, small lots of coils are transported on hand trucks.



1.—Ready to load. Reel arms are adjusted inward; spindle is locked.



2. Raising coil. One man raises a 300-lb. coil easily.



3.—Coil is loaded with little effort.

4.—Centering the coil by turning the arms like a capstan.

FIG. 320.—Illustrating an easy method for one man to mount heavy coils of stock on the Littell patented centering reel.

After delivering coil stock at the presses, the coils can easily be lifted and mounted on their respective centering reels, as seen in Fig. 320. Without some kind of device for mounting large coils that

weigh up to three or four hundred pounds, it may require two or three men to place them on the reels, and at the risk of serious accidents.

Duralumin

Aluminum	95 per cent
Copper	3.5 to 4.0 per cent
Magnesium	0.2 to 0.8 per cent
Manganese	0.4 to 1.0 per cent
Silicon	Under 0.6 per cent
Iron	Under 0.6 per cent
Tensile strength	55,000 lb. per square inch
Elastic limit	32,000 lb. per square inch
Elongation in 2 in.	18 per cent
Brinell hardness	50

Duralumin is a lightweight material and has been largely used in airplane work. It is symbolized under the 17S series of aluminum.* It is the most widely used of all the heat-treatable aluminum alloys. However, in recent times, Duralumin has been almost entirely superseded by 24S aluminum for airplane parts, because the 25 per cent higher yield strength of the latter alloy is translated directly into correspondingly superior performance. The higher physical properties of this alloy also make possible the use of Alclad sheet with a material gain in strength as well as resistance to corrosion, in comparison with 17S sheet.

Severe forming operations have been accomplished with the soft tempers, such as 17S-O and 24S-O, but the finished parts must always be heat-treated before assembly. If this is not done, both their physical properties and resistance to corrosion are definitely inferior.

In working Duralumin the sheet is first heated in a salt bath or air furnace at 930°F. and then quenched in cold water. It is then rinsed in warm water. Every effort must be made to perform bending operations within 1 hr. after quenching; otherwise checks and cracks may appear. The hardness, or temper, is unimportant on flat work. Small parts that require several die operations can be kept in workable condition by storage at low temperatures. It is best to take these precautions; otherwise the cracks may show up after final assembly in the apparatus. If the sheets are large, means for flattening must be provided, as the salt bath distorts the sheet.

For Duralumin rivets, either large or small, it is important that they be annealed at an exact temperature each hour and a routine established to collect those not used within the hour. On large-quantity production on some of the parts the same procedure may be

* The mechanical properties of wrought-aluminum alloys are given in Chap. XVI, p. 465.

found necessary. The specific gravity and weight per cubic inch is 3 per cent heavier than for sheet aluminum. The specific gravity is 2.80; the weight per cubic inch, 0.1010 lb.

Piercing, Blanking, Lancing, Drawing, Forming, and Trimming Simultaneously.—Many of the intricacies involved in the details of progressive dies can be better understood from good photographs of

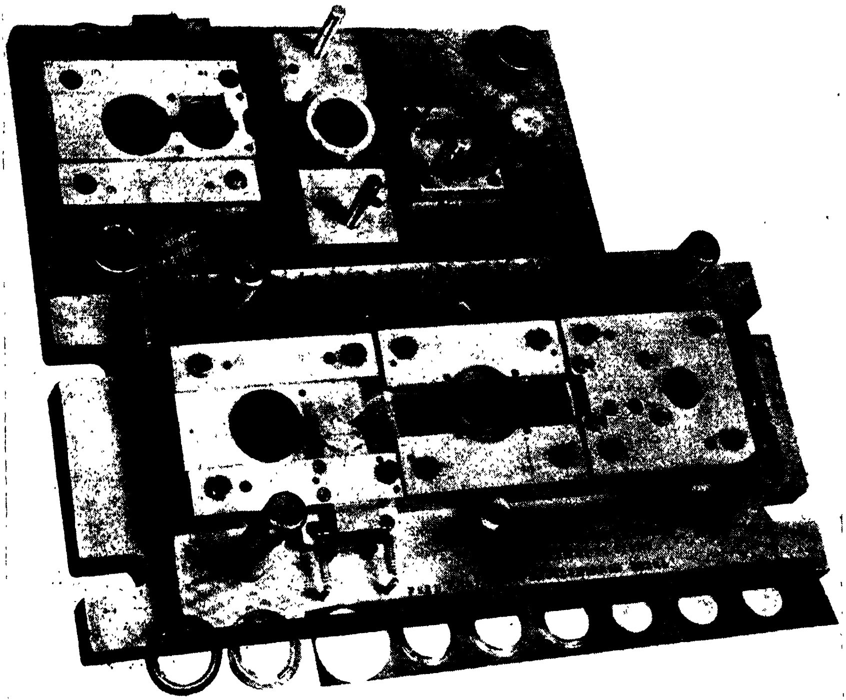


FIG. 321.—Seven-station progressive punch and die of high-grade construction; this press tool turns out hundreds of thousands of hinged frames used on ladies' vanity cases. Scrap strip in front of the die shows the consecutive order of operations and also two lines of piloting holes in the edges of the strip for registering the work at each station.

the assembled tool than from draftsmen's drawings. The following three photographs of dies were lent by the Moore Special Tool Co., who are experts in designing and building these dies and have also launched a line of special machines, such as jig-boring and grinding equipment, to expedite the construction and assembly of progressive dies.

Figure 321 is a photograph of a progressive die used in fabricating a 0.0156-in. steel frame which is the hinged part of a ladies' vanity

case. Figure 322 is a close-up view of the part made in this die. Many thousands of these parts were required, hence the necessity for making this high-grade progressive die.*

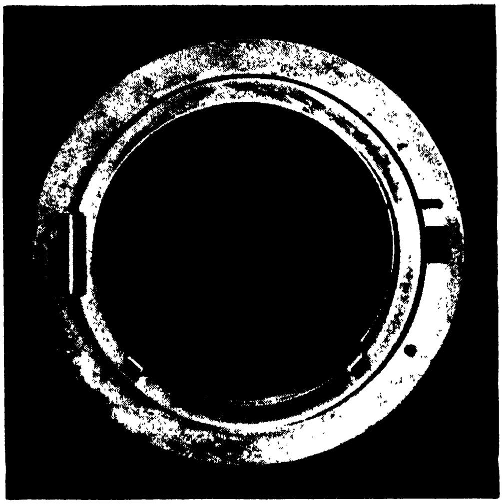


FIG. 322.—A close-up view of the steel frame fabricated in the die shown in the preceding figure.

Order of Operations

Beginning at the right end of this die at station 1, two piloting holes are pierced and a large center hole "blanked out." The latter is subsequently used for drawing or extruding the inner rim.

At station 2, two lugs are lanced or sheared in the edge of the center hole, but station 3 is idle.

Station 4 is a compound punch and die in which the center-hole rim is drawn, or "extruded," as it is sometimes called. The work and strip must be "freed" at this station so that the strip can be passed along. Spring shedders in the punch and die free the work. Notice the extra pair of leader pins used at this station to ensure stability of operation. A hinge bearing is also extruded at this station.

Station 5 is also idle. The purpose of making stations 3 and 5 idle is to provide an extra supply of metal around them from which to draw the rim in station 4.

At station 6 the two lanced lugs are formed straight out from the edge of the drawn rim, by using the sliding block in front of the die as

* In the author's *Pressworking of Metals*, McGraw-Hill Book Company, Inc., New York, is an extensive account of the quality grades of press tools, together with a complete "Check List for Designers," showing how to avoid difficulties when designing progressive dies.

an anvil. These two lugs must be brought into exact position and be flat. Two small rectangular holes are also pierced at this station.

In station 7 the outside diameter of the piece is trimmed out of the strip, and the punch, continuing to descend, pushes the finished piece through the die.

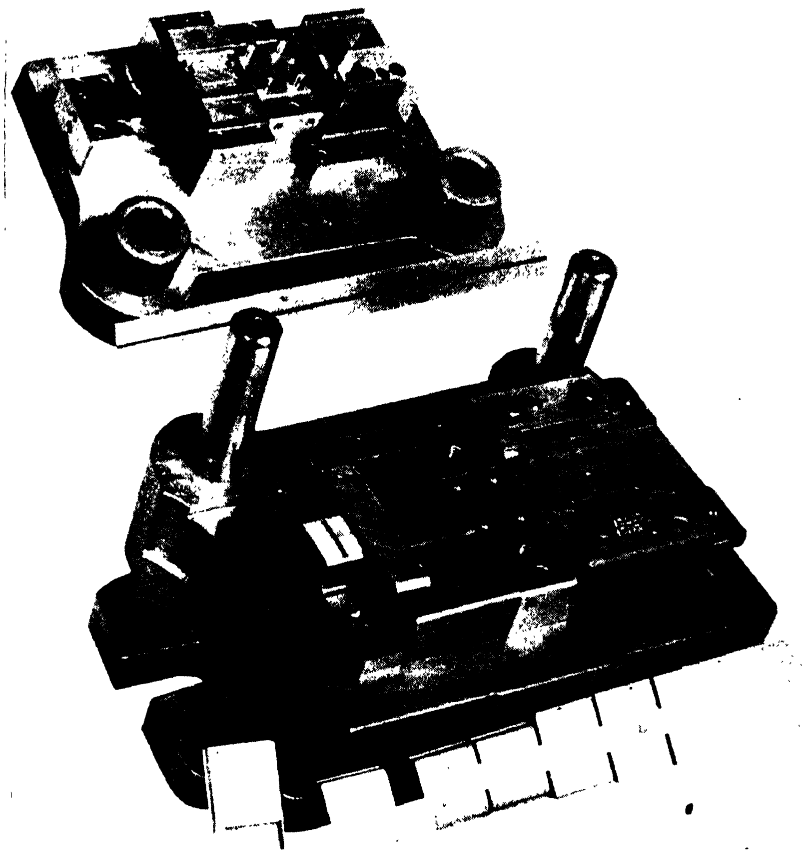
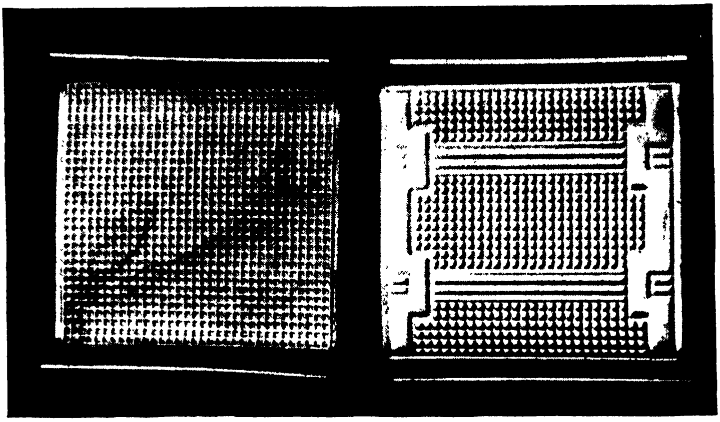


FIG. 323.—Progressive die for producing large quantities of cigarette-lighter bodies. Scrap strip in front of the die shows consecutive order of operations.

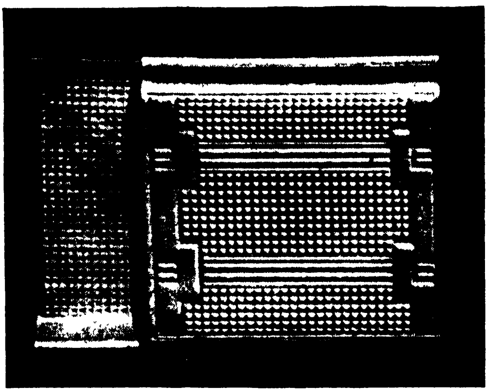
It is noticed that two piloting punches engage in corresponding die holes at each of the stations. This feature registers the strip and work correctly each time the punches descend.

Fabricating Cigarette-lighter Bodies.—Figure 323 is a picture of a progressive die for producing large quantities of cigarette-lighter bodies. The parts are made in halves and are subsequently slided

together and soldered in assembly. The material is 0.0126-in.-gage sheet brass. Figure 324 is a close-up view of the work.



A



B

FIG. 324.—Close-up views of the parts made by the die in the preceding photograph. *A*. The half parts before they slide together. *B*. The parts sliding together by means of tongues and grooves in the edges.

Order of Operations

Station 1, slit and trim to width. Station 2, form bead on edge. Station 3, form and emboss ornamentations. Station 4, idle. Station 5, cut apart.

To make a cigarette-lighter body of this type, two dies like this one are required, one "male" and one "female." The die shown in the picture is called the "female."

Fabricating Mechanical Time Fuses.—The compound punch and die shown in Fig. 325 has been taken apart and the respective pieces

laid beside the punch holder and die shoe. It will be found good practice for the prospective designer to visualize how these pieces must be assembled in order to make a perfect working tool. What are the names of all these parts, and what is their function in the completed

FIG. 325.—Here are all the necessary parts of a compound punch and die for fabricating mechanical time fuses.

tool? What would be the shape and appearance of the mechanical time fuse produced in this die?

Using Kirksite "A" in Aircraft Work.—Kirksite is a new alloy of metals which has recently been introduced into die shops. It was

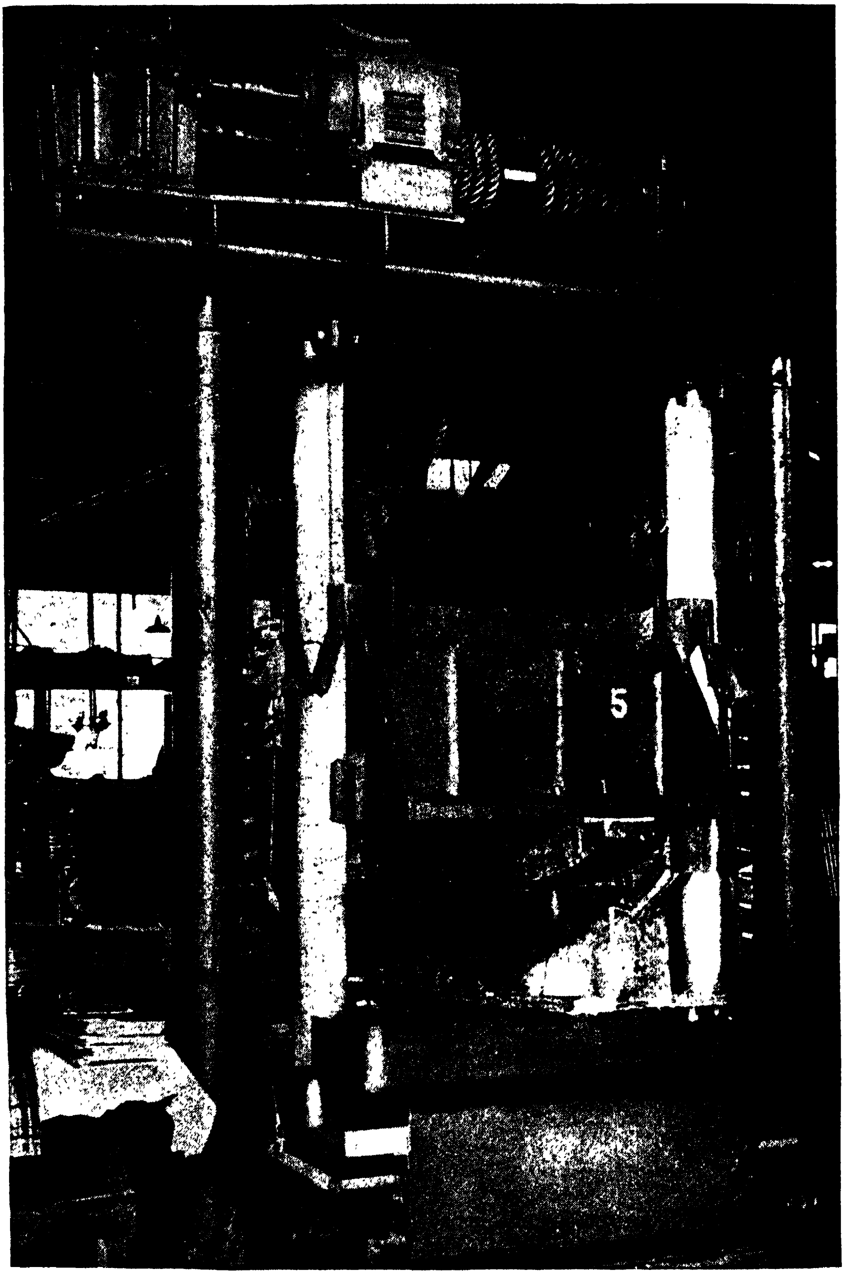


FIG. 326.—Kirksite "A" die secured on the anvil of a drop-hammer press. This is a progressive-type die, and each hammer blow extends the formed portion of the work a little farther along and, in this case, increases the curvature in the work a little at a time until a complete circle is formed. This is a rear view of the press.

primarily brought into use for shaping certain aircraft parts in forming and drawing dies. This material was very much needed for quick and dependable construction of the working members of both large and small punches and dies. Sponsored by the National Lead Company, this alloy has almost entirely replaced materials formerly used in the building and operation of certain stamping dies. Many thousands of

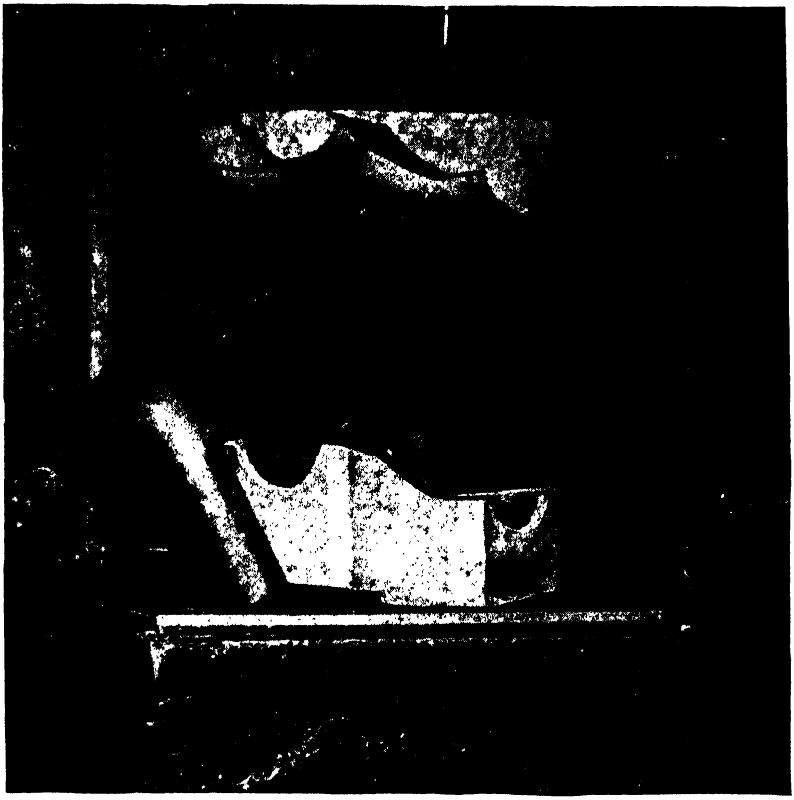


FIG. 327.—Kirksite "A" punch and die, which has produced 2,800 exhaust-manifold parts of 0.038-in. gage Stainless steel. This tool is still serviceable. A finished sample of the work is shown at the left. (*View taken at Solar Aircraft Company's plant.*)

tons of Kirksite have gone into the punch-and-die parts of hundreds of thousands of press tools in the United States and Canada. Its great popularity seems to have been sustained because of its unusually good physical characteristics, which include excellent casting properties, ease in polishing and machining, physical properties approaching those of mild steel, good resistance to abrasion, adaptability to welding operations, and very small losses of dross when remelting.

Physical Properties of Kirksite Castings

Compressive strength	60,000 to 75,000 lb. per square inch
Melting point	717°F.
Weight per cubic inch	0.250 lb.
Weight per cubic foot	432 lb.
*Elongation in 2 in	3 per cent
Coefficient of linear expansion	15.4×10^{-6} per degree Fahrenheit

* Rolled sections have an elongation of 30 per cent in 2 in.

Figure 326 is a photograph of a Kirksite die under severe use in the form of percussion dies shown under the heavy blows of a large drop-hammer press in the Ryan Aeronautical Company's plant. This die

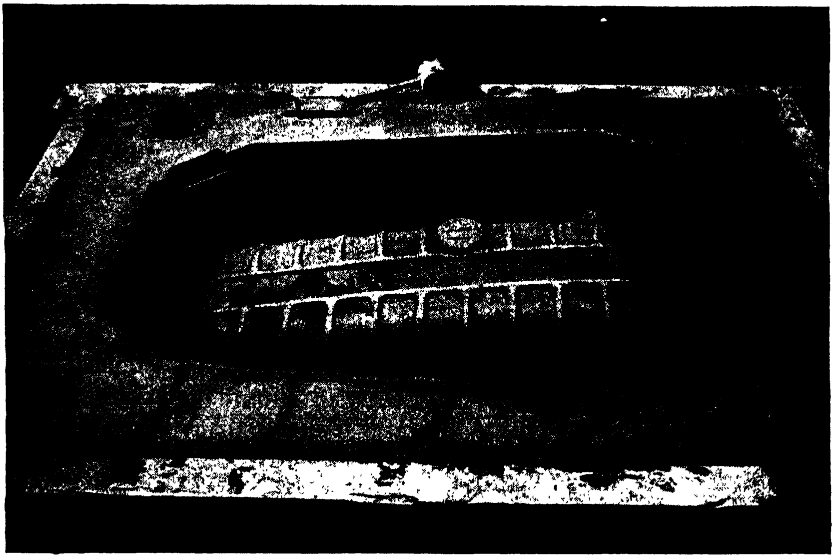


FIG. 328.—Sand mold for casting a stamping die for a large-section gasoline tank. Notice the four impressions at the outer corners for casting hold-down flanges.

material is also largely used for shaping aircraft parts under the pressure of a rubber platen as used in the Guerin process.

Figure 327 shows a typical setup of a Kirksite punch and die in a large hydraulic press. This punch and die was cast in a mold, after which its working surfaces were partly polished. The part produced is a section of an exhaust manifold, and the sample at the left shows how well these dies stand up after having drawn and formed nearly 3,000 pieces.

Figures 328 and 329 show how castings for dies are made from Kirksite. In the first picture is shown a sand mold for casting the 2-ton die seen in the next view. No finishing or polishing work was

necessary in this die, and this tool had drawn and formed over 350 parts of an aircraft gasoline tank before this photograph was taken. Notice that there are no worn edges or damaged surfaces in this die. The photograph has not been retouched.

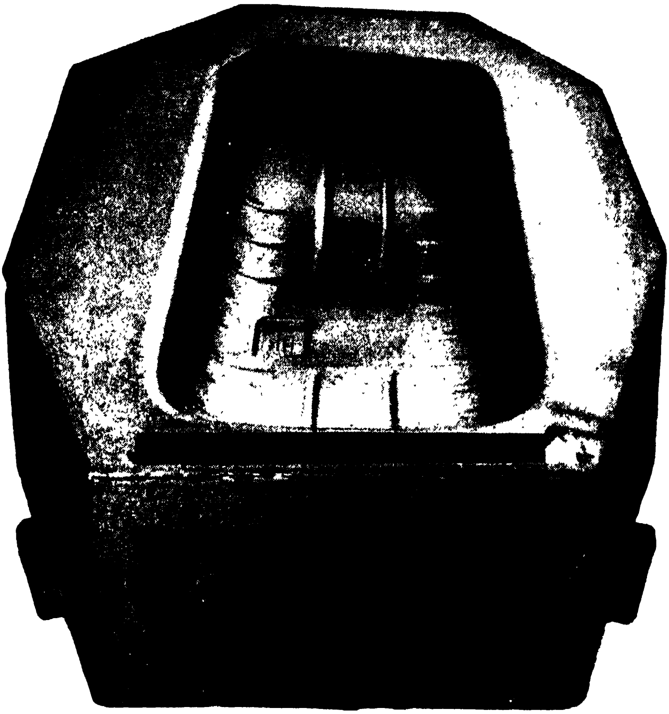


FIG. 329.—Kirksite "A" die produced from the mold shown in Fig. 328. This die weighs over 2 tons and is a part of a set of four. No finishing has been done to this die, and the photograph has not been retouched. The die has been in intermittent service for a year and has produced over 350 stampings.

Forming and Trimming with Kirksite Dies.—Many times these two operations can be performed consecutively. An example of this is illustrated in Fig. 330. There is only one punch and die shown in this illustration. At *A*, the work sheet has been placed over the die and the punch is ready to descend. At *B*, the punch has descended and formed the two rims and bulge on the sheet. At *C*, semisoft-rubber blocks have been placed over the sheet and slots in the die, and at *D*, the punch has descended again and compressed the rubber. The result at the extreme downstroke of the punch is that the sheet is trimmed according to the position of the cutting edges in the die. Shapes of the cutting edges may be straight lines, arcs, or irregular curves.

Square-edged Trimming Shells of Various Shapes.—Drawn shells of any shape—round, square, or rectangular—can be trimmed squarely and accurately, or trimmed with notched edges, in a single quick operation by using a Bliss flat-edge trimming press.

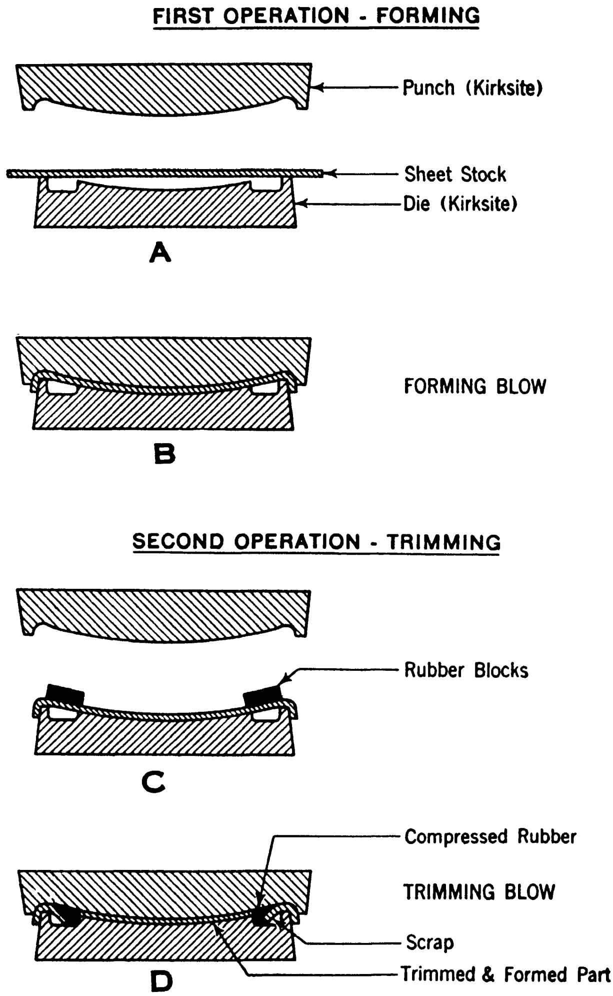


FIG. 330.—Showing the punch-and-die design and necessary sequence of operations in forming and trimming sheet metals in Kirksite dies.

The five sketches in Fig. 331 illustrate the die operations necessary for flat-edge trimming. At the left is shown the upper die, which carries a filler pad free to float on its surface. The lower die is provided with a spring knockout pad, and a shell is shown placed on the pad, within the die, ready for trimming.

The punch, as shown, is provided on each side with stop strips that are ground true and parallel with the ground surface of the lower die. These strips clear the edges to be trimmed from the shell when they descend with the punch and stop upon the die. In operation, the filler pad, in descent, enters the shell and depresses it to the required trimming depth in the lower die.

The press slide is cam driven and is designed to dwell at the completion of the downstroke during the trimming interval. A slight motion, sufficient for shearing off the scrap, is then imparted to the *lower* die, which cuts front, back, right, and left against the upper-die edges. By this action the scrap is sheared off and is ejected by an air blast when the slide ascends and the dies are opened. The side-trimming operations are shown in the third and fourth views (Fig. 331), and the end cuts are similarly made. The horizontal slide in the press bed, which imparts the shearing motions to the lower die, is operated from the rear of the press by a vertical shaft driven by miter gears from the main shaft.

Brehm Trimming Dies.—The Brehm trimming die, a patented tool, does flat-edge trimming of drawn shells in an ordinary single-action press. The actual shearing-off operation is similar in principle to the trimming dies just described under Fig. 331, but the special punch press is not required.

The punch, in descent, enters the shell placed in the lower die and depresses it to the proper shearing level against a spring pad, as in the previous examples. Shearing motion is imparted to the lower

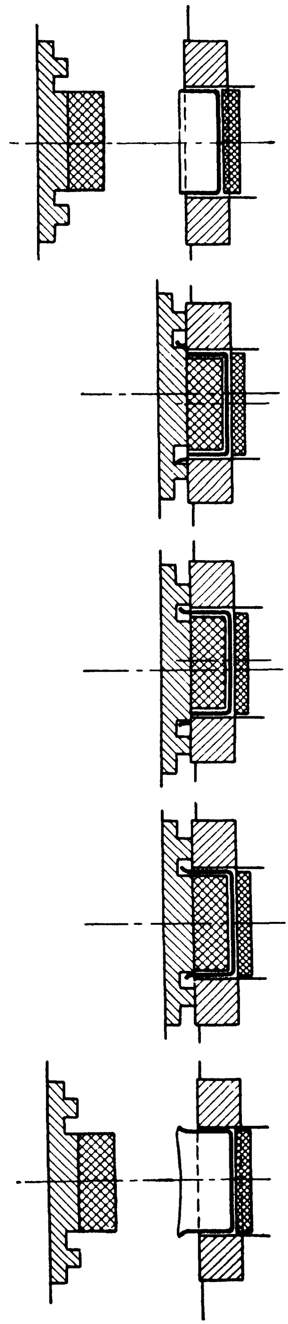


Fig. 331.—In the Bliss flat-edge trimming press, when the tools are closed, a slide in the bed imparts a sideward motion to the lower die, thereby shearing off the scrap around the top of the shell.

die by a series of horizontal cams cut in its sides, which contact stationary cam projections in passing them. This peculiar motion, which follows several directions in descent, has led to the popular name "shimmy die."

This die trims, and notches if necessary, all the many varieties and shapes of large or small shells. It is necessary, of course, to build special cutting adapters to suit the different sizes of shells to be trimmed in the same die set, as is the case in all trimming dies. Large work such as the parts for burial caskets, of 0.109-in. sheet, have been rapidly trimmed and notched, 2,000 pieces being finished in 6 hr.

Multiple-plunger Eyelet Machines.—A front view showing one of these machines is presented on Plate XIX, page 426. The machine in the picture has 11 vertical plungers, and as many as 11 different drawing operations can be performed in one revolution of the crankshaft. In the lighter types of these machines the plungers are actuated by cams; the heavier models are crank driven like the one shown here. The plungers are in straight vertical alignment and occupy practically the entire length of the press bed. Strip is fed in at the first station on the right; here the blank is cut and then shallow drawn in a combination die. The strip passes across the die at right angles to the press bed and is fed from a reel that stands in front of the machine. The scrap strip passes out at the rear, where it is bundled on a reel scrap winder.

The work is transferred from station to station for redrawing operations by a centralized pair of gripping fingers at each station. They are attached within a reciprocating frame that slides on the surfaces of the dies. On the upstroke the shells are raised from the dies by a knockout underneath. They are then lifted into the transfer slide as the plungers ascend and are engaged by the gripping fingers, which carry the shells one station forward for subsequent drawing operations.

This machine is used largely in the manufacture of small shells, under about 2 in. diameter, small cartridge cases, eyelets, mechanical-pencil tips, radio-tube grids, primer caps, tubes, and similar parts requiring high production. One of its many advantages is that the shells are continuously redrawn while still warm, and this is a favorable condition in avoiding ruptures in the work.

An Improvised Coil Stock Reel.—Figure 332 shows the design and gives the dimensions for building an adjustable coil stock reel. The base can be made from a scrapped punch holder and the other parts picked up around the shop. This is a ball-bearing reel, but this feature can be omitted if oil holes are provided for properly lubricating the bearings used. The 12-in. diameter disks on each side of the coil can

be made of laminated wood stock and made enough larger than shown to confine large coils of narrow strip. By adjusting screw *A* and tightening its lock nut, this reel can be tipped at an angle to suit the inclination of the press. Some shops have built a dozen or more of such reels for their own use.

Drawing and Annealing Rim-fire Cartridges.—Cartridges made of brass stock, Admiralty metal, or preferably "cartridge brass" are composed of 68 to 70 per cent of copper and 30 to 32 per cent of zinc. "Pure Lake" or "Electrolytic" grades of copper are specified 99.88 per cent pure, the remainder being small quantities of lead and iron. Zinc used is specified as "grade A," Brinell hardness for No. 12 Brown & Sharpe gage (0.0808-in.) brass strip being between 50 and 65. Admiralty metal is practically the same composition as cartridge brass.

Rim-fire cartridge shells are blanked and drawn in dies having tungsten-carbide drawing rings. Six to eight cupping shells are drawn at each stroke of the press. The shell walls are drawn thinner than the original thickness of material; therefore the shell bottom is slightly thicker than its sides. Three to four redrawing operations are usually necessary, depending, of course, on the percentages of shell reduction. The last operation consists of trimming off the mouth of the shell squarely. The shells must be washed after each drawing operation to remove the drawing compound. After washing, the shells must be furnace annealed to relieve drawing strains. After the shells are annealed, they are "pickled" to remove scale caused by heating.

Annealing large quantities of small parts is done in a "tumbling barrel," or drum. The drum is composed of a heat-resisting casting. A large number of holes are drilled through the walls of the drum, to admit heat, but the holes are small enough to prevent parts from falling out. The drum revolves and tumbles the work within the even heat of a closed-in annealing furnace. Cartridge shells are usually dumped from the annealing drum into an acid washing solution contained in another revolving barrel. This is the pickling solution that removes the gritty annealing scale, which is very injurious to the interiors of drawing dies.

After several redraws, the open ends of the shells become "ragged" and "wavy." This condition interferes with accurate automatic feeding in subsequent drawing die operations. The shells are usually trimmed after the third or fourth redraw, depending, of course, upon their ragged or wavy condition. Trimming is done on a small automatic lathe, equipped with automatic hopper feeds. The output is around 65 to 75 trimmed shells per minute.

Die operations for heading cartridge rims are shown in the principles set forth in Fig. 333. The shells are agitated in a hopper, not shown, which causes them to enter chute D. If the open end of a shell enters the chute, the shell is turned end for end by striking hook E in magazine F. The shell is caused to fall, closed end down, as desired. This well-

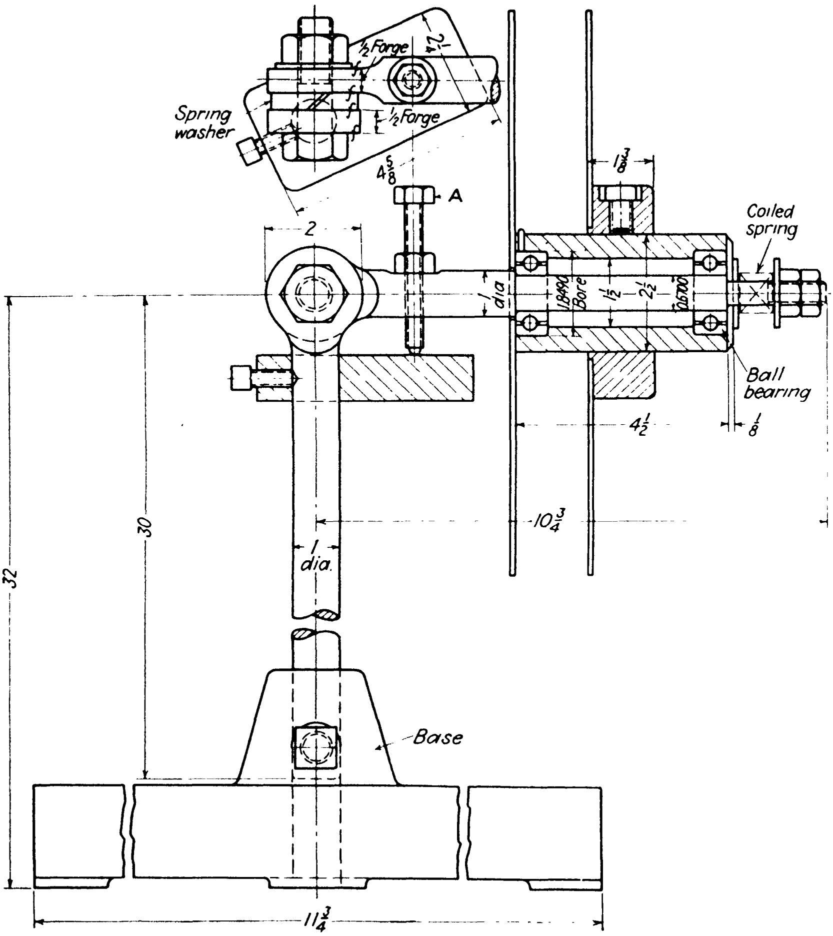


FIG. 332A.—Low-priced ball-bearing reel from which coil stock can be fed to dies. This reel can be built in any ordinary machine shop.

known principle is often employed for reversing pieces of work before they enter dies and special machines for further operations. For irregularly shaped pieces, the hook contour is shaped to suit indentations in the work. If a shell enters the magazine closed end first, the head of the shell hits a point on the hook; the shell rebounds slightly and then falls head first into the magazine in regular order. Slide G pushes the shells ahead against a stop and under the punch-press tool.

A pilot on punch *A* enters the shell, and a shoulder on the punch pushes the shell down into the die. When the shell protrudes through the die, as seen at *A*, an anvil is advanced by a cam underneath as shown at *B*. Sketch *C* shows the rim completed. This operation is called "beading" and is a principle often resorted to in many other

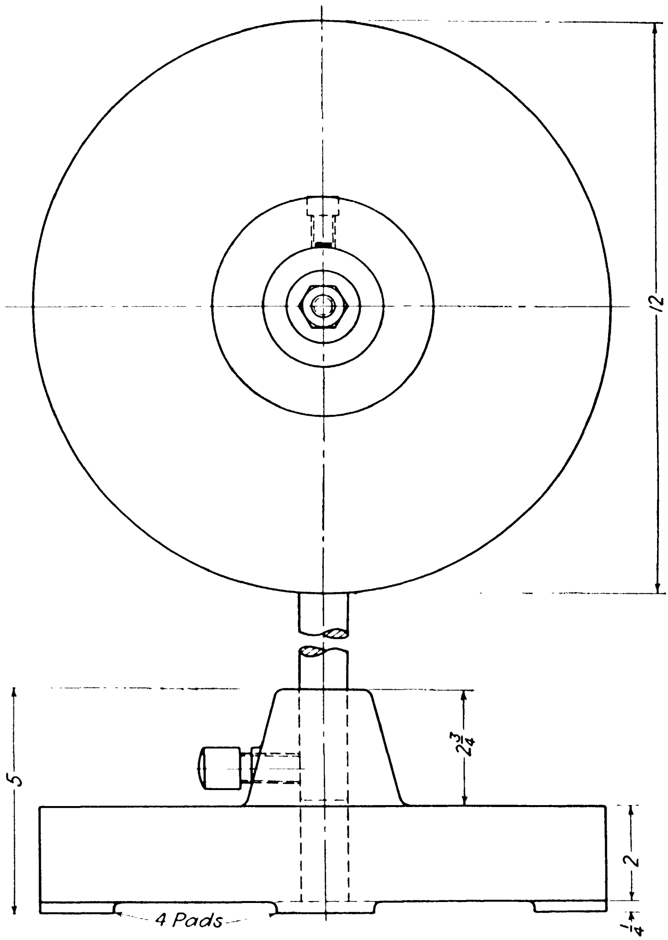


FIG. 332B.—A right-hand projection of the front view of Fig. 332A.

types of die-worked parts. After the rim has been formed, a quick fall in the cam causes the anvil to recede suddenly, and the finished shell is pushed through the die.

Drawing Small-caliber Shells in Eyelet Machines.—Small-caliber cartridge shells can also be blanked and drawn in multiple-plunger eyelet machines, and annealing can be avoided by using materials of sufficient ductility. The metal will withstand more frequent redraws

without annealing because the shells are worked continuously while still warm. Beading is done in the last station, just before the shell is pushed through the die. Continuous redrawing operations are more advantageous than drawing operations done in separate dies, in which the metal becomes cold between the draws, but of course this can

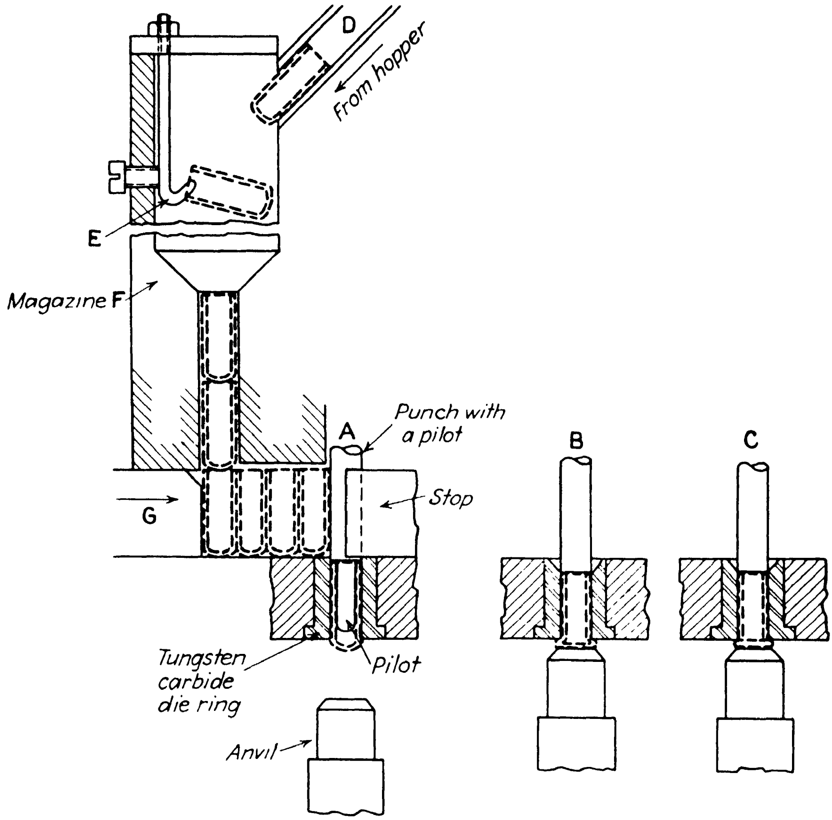


FIG. 333.—A shouldered pilot punch at *A* pushes the shell partially through the die and momentarily holds it there. The cam-actuated anvil then rises from below and "beads" the shell rim, as seen at *B* and *C*.

only be done when using very light-gage ductile materials and when the shells are small (see Plate XIX, page 426).

DRAWING ARTILLERY CARTRIDGE CASES

Drawing 75-mm. Shells at Frankford Arsenal.*—The first operation is cupping of a commercially procured blank of dimensions shown

* Frank J. Lerro, foreman, Artillery Cartridge Case Shop, Frankford Arsenal, in *American Machinist*, vol. 84, p. 667. The views expressed are solely those of the writer and in no way reflect the attitude of the War Department. The statements made and figures quoted are not from official sources.

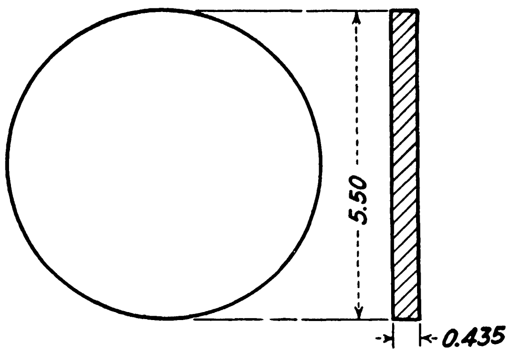


FIG. 334.—This blank provides the dimensions of the raw material for drawing a 75-mm. cartridge case. Obtaining the metal in this form, rather than in sheet, saves handling of scrap.

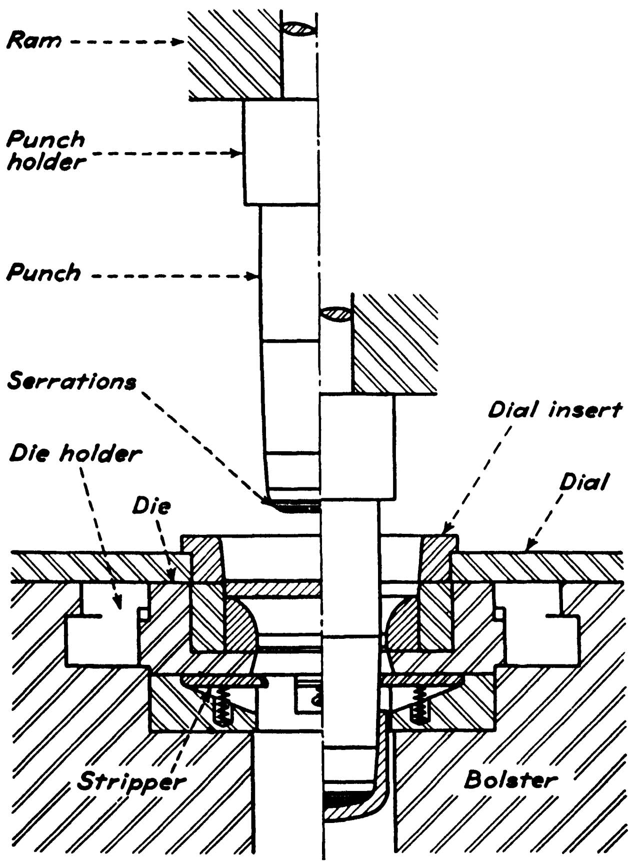


FIG. 335.—The cupping operation is done in an eight-station dial-feed press. Disks are fed sharp side down.

in Fig. 334. This blank is made of cartridge brass (70 per cent copper and 30 per cent zinc), having a Brinell hardness (500-kg. load, 10-mm. ball) of 43 to 65, and a tensile strength of 40,000 lb. per square inch, with a grain size of 0.055–0.115 mm., magnification × 75.

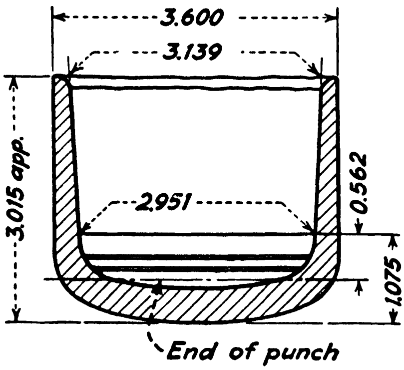


FIG. 336.—Cups are drawn to these dimensions. They must be free from grooves that might be carried through into subsequent redraws.

This operation is done on a mechanical press equipped with an eight-station dial feed. It is cupped in the die shown in Fig. 335. The final dimensions of the cup are shown in Fig. 336.

The blanks are fed into the die nest, sharp side down, to obtain the best drawing edge in subsequent redraws. If this drawing edge has the slightest gutter around the middle of the side wall at the top of the cup, it will form a gutter or groove on the inside surface of the side wall in the following redraws and, in all probability, will cause tearing of the metal at this point. This is caused by the metal of the side walls tending to fold around the punch while drawing through the die.

Because of the importance of proper design of the cupping die, a detailed view, Fig. 337, is shown. The design of this cupping die,

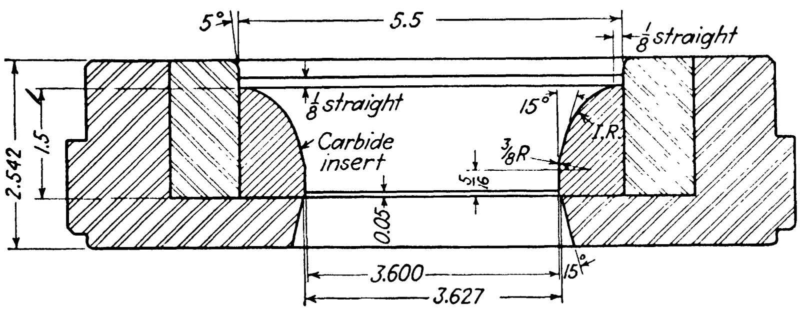


FIG. 337.—A sectional view through the cupping die showing the carbide insert that takes the maximum abrasion when drawing shells.

along with the serrations on the nose of the punch, has proved satisfactory in holding enough metal at the base to permit heading the cases without relying on an indenting operation to accumulate enough metal to do so.

One hundred and twenty-five tons press pressure are required to perform this operation. The drawing speed used is approximately

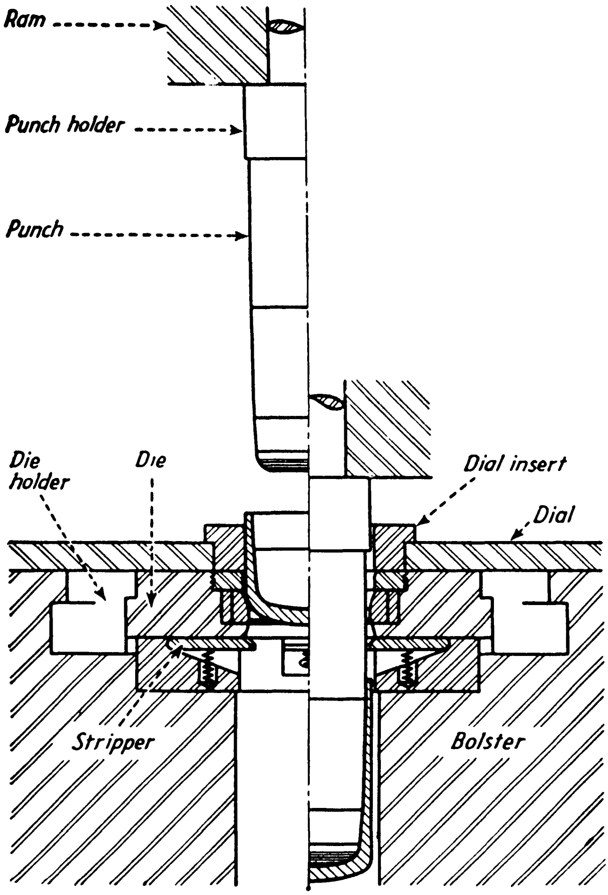


FIG. 338.—A dial-feed press is again used for the first redrawing operation. A 70-ton pressure is required, and a press of suitable capacity is used.

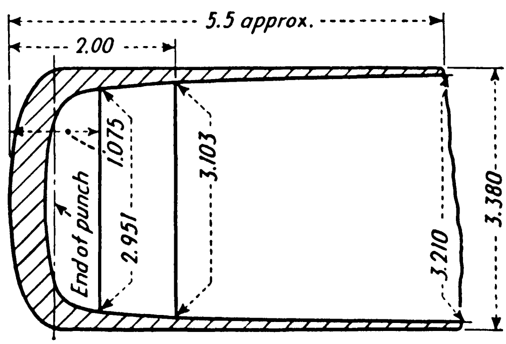


FIG. 339.—Dimensions after the first redraw show a 35 per cent reduction at the bottom of the shell and 60 per cent at the top.

75 ft. per minute. The reductions in wall thickness vary from 30 per cent at the bottom wall to 50 per cent at the top wall of the cup. There is also a reduction of 35 per cent in the blank diameter.

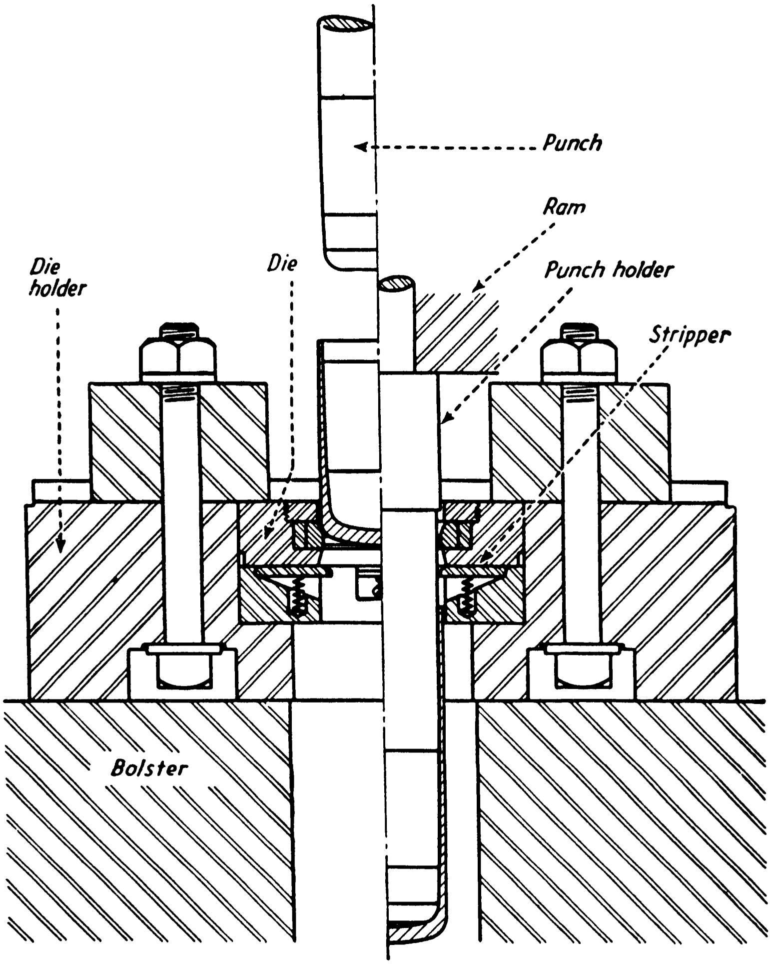


FIG. 340.—In the second redraw the cases are fed into the die by hand. The extra length of press stroke required renders a dial feed unnecessary.

Annealing Artillery Shells.—Following the cupping operation, and after the first and second redraws, the cases are annealed in "batch-type furnaces" to a temperature of 1125°F. and are left in the furnaces to obtain the following grain size at mag. $\times$ 75: After the cupping and first redraw, 0.060 to 0.080 mm. After the second redraw, 0.035 to 0.045 mm.

After the cases are annealed, the basket containing annealed work is lowered into a large tank and sprayed with cold water. This same basket (15 per cent chromium and 35 per cent nickel) is carried into another tank containing a 12 per cent (by weight) sulphuric acid solution. The cases remain in this solution for approximately 2½ min., after which they are lowered into tank 2 for a plain cold-water rinse; next they are placed in tank 3 containing a soap solution (0.2 per cent by weight of soap chips, 0.2 per cent by weight of alkaline cleaner, and the remainder water) maintained at a lukewarm temperature to prevent excessive lather. Finally they are washed in tank 4, containtaining plain hot water to rinse the cases thoroughly and to quicken drying. The cases are then ready for the following redraws.

First Redraw.—The first redraw is performed in the same manner as the cupping operation, using a mechanical press equipped with a dial feed. Seventy tons press pressure are required to perform this operation, and a drawing speed of 65 ft. per minute is used. The reductions taken on this redraw are 35 per cent at the bottom of the case and 60 per cent at the top of the side wall. Figures 338 and 339 show the setup for this operation and the first redrawing dimensions.

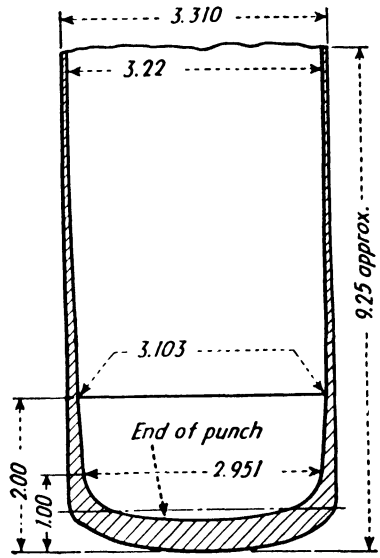


Fig. 341.—Dimensions of the 75-mm. case after the second redraw show reductions varying from 40 per cent at the bottom to 50 per cent at the top.

Second Redraw.—The second redrawing operation is done on a high-speed hydraulic press; the work is fed into the die (Fig. 340) manually, as the stroke required gives the operator ample time to have the work ready for the next stroke of the press. This operation requires approximately 35 tons working pressure, and the drawing speed used is 40 ft. per minute. The reduction in wall thickness varies from 40 per cent at the bottom of side wall to 50 per cent at the top. For the final dimensions see Fig. 341.

Third Redraw.—The third and final redraw (Fig. 342) is carried on in the same manner as the previous operation with the exception that the working pressure required is 30 tons and the drawing speed 35 ft. per minute. The reductions (Fig. 343) are from 50 per cent at the bottom of the side wall to 30 per cent at the top. This governs

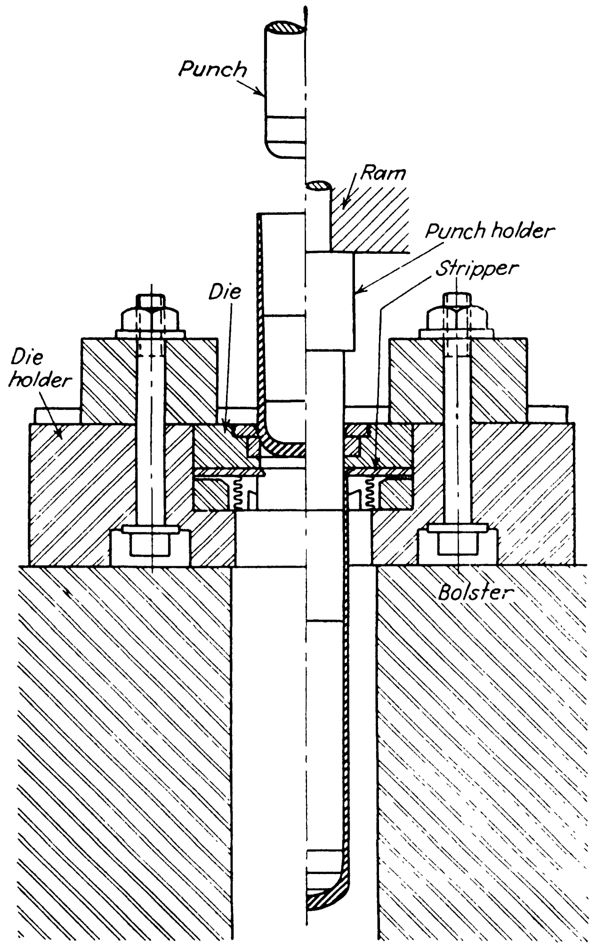


FIG. 342.—As the shell wall becomes thinner, the press pressure required is less, but the drawing speed must be reduced.

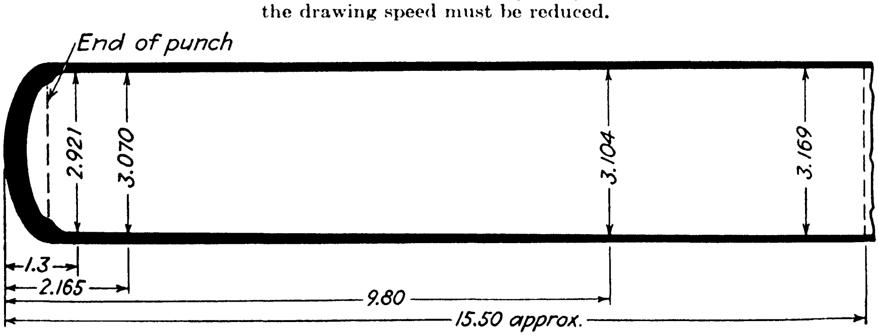


FIG. 343.—If the case is given proper pressworking, it will have a tensile strength of 85,000 lb. per square inch after the third redraw.

the final physical requirements of 85,000 lb. per square inch tensile strength near the bottom of the side wall.

Conclusion of the Drawing Operations.—Before leaving the drawing operations, it might be well to mention that all the presses used are

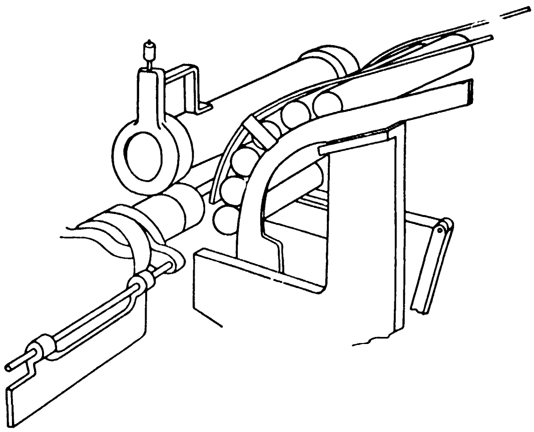


FIG. 344.—The first trimming operation is made in an automatic magazine-feed machine after the third redraw. A photograph of this machine is shown on Plate XXXI, page 439.

equipped with forced-feed lubricant pumps, with the exception of the cupping press, where the blanks are dipped by hand into the lubricant pan and placed into the bushings of the dial feed ready to be fed under the punch.

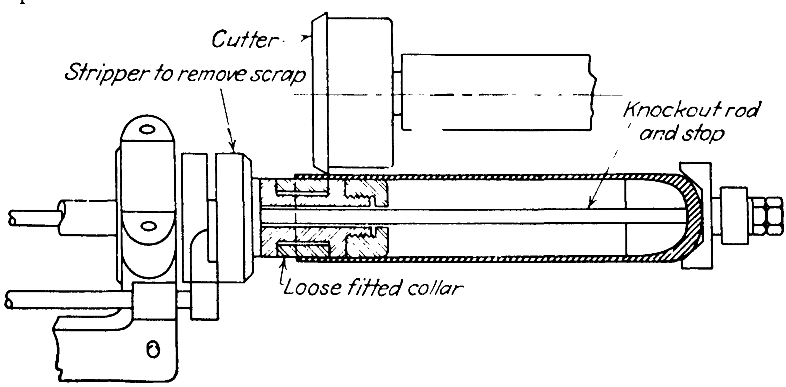


FIG. 345.—A detail of the setup for shearing the first trim in the preceding figure, showing how the shell is held and end trimmed off.

Carbide insert dies are used throughout because of the severe reduction and high production of the presses. This type of die requires less maintainance because the damage from brass "pickup" and die wear is less.

After each drawing operation, the cases are washed in hot water in individual tanks at the presses to remove drawing compound and then loaded into the annealing baskets. On the way to the furnace, they are again washed in a centrally located tank containing hot water. This ensures unspotted clean-finished cases.

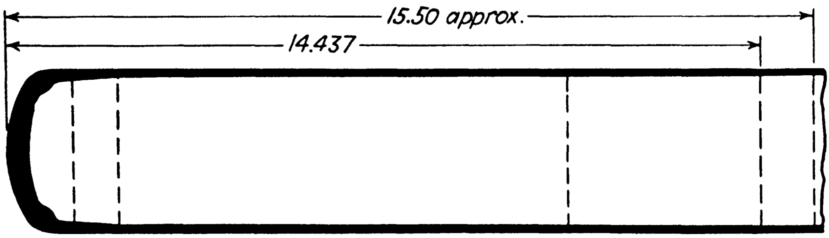


FIG. 346.—These are the trimming dimensions that prepare the shell for the heading operation.

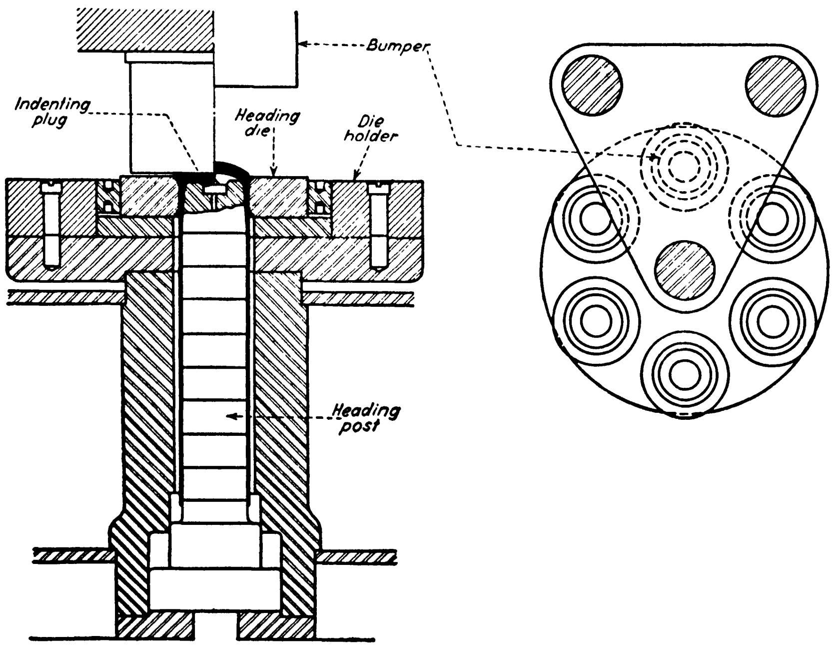


FIG. 347.—Heading and indenting are performed simultaneously in a dial-feed hydraulic press.

Trimming Artillery Shells.—Following the third redraw, the cases are ready for the first trim of the mouth end of the shell. This operation is performed on an automatic end-trimming machine equipped with a magazine feed, as shown in Figs. 344 and 345. (See also p. 438.)

Heading and Indenting Artillery Shells.—After the cases are trimmed to the dimensions shown in Fig. 346, they are ready for heading and indenting operations that are performed on a 1,000-ton hydraulic heading press equipped with a six-station dial feed, shown in Fig. 347. The base of the case is given a light coat of beef tallow or drawing-compound paste to facilitate the spreading of the metal toward the outer edge while the pressure is being applied by a heading bumper having a ¾-deg. convex angle along its face.

The indenting of the primer hole is done to prevent expansion of the primer seat during service. This operation is performed in conjunction with the heading operation by inserting a plug into the primer boss cavity of the heading nose in the die. The dimensions of the plug are 0.480 in. at the base and 0.310 in. in length, pointed to a $\frac{3}{32}$-in. radius. This plug so displaces the metal as to give a Brinell hardness of 130 to 140 (using a 15-kg. load and $\frac{1}{16}$-in. steel ball) just beyond the walls of the finished primer hole.

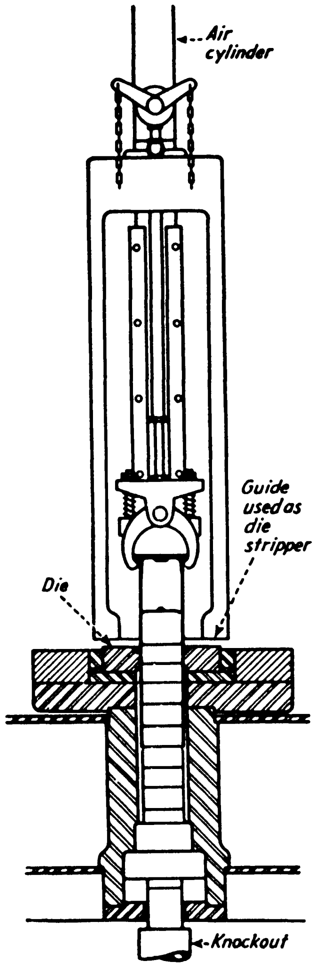


FIG. 348.—A pneumatically operated gripping fixture lifts the case from the heading die.

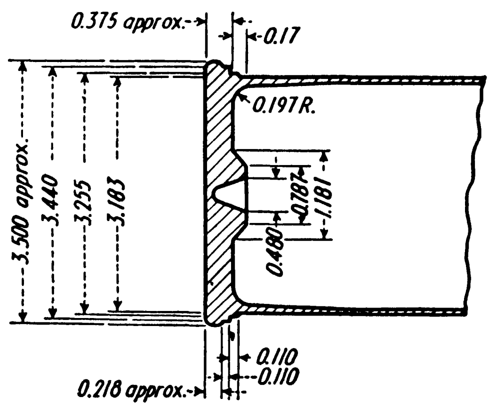


FIG. 349.—Dimensions of the head and indentation show how the accumulated metal has been forced into its proper place.

After a case is headed by the bumper, which exerts a pressure of 675 tons, it is indexed to the unloading station and ejected as shown in Fig. 348. Care should be exercised during this operation to see

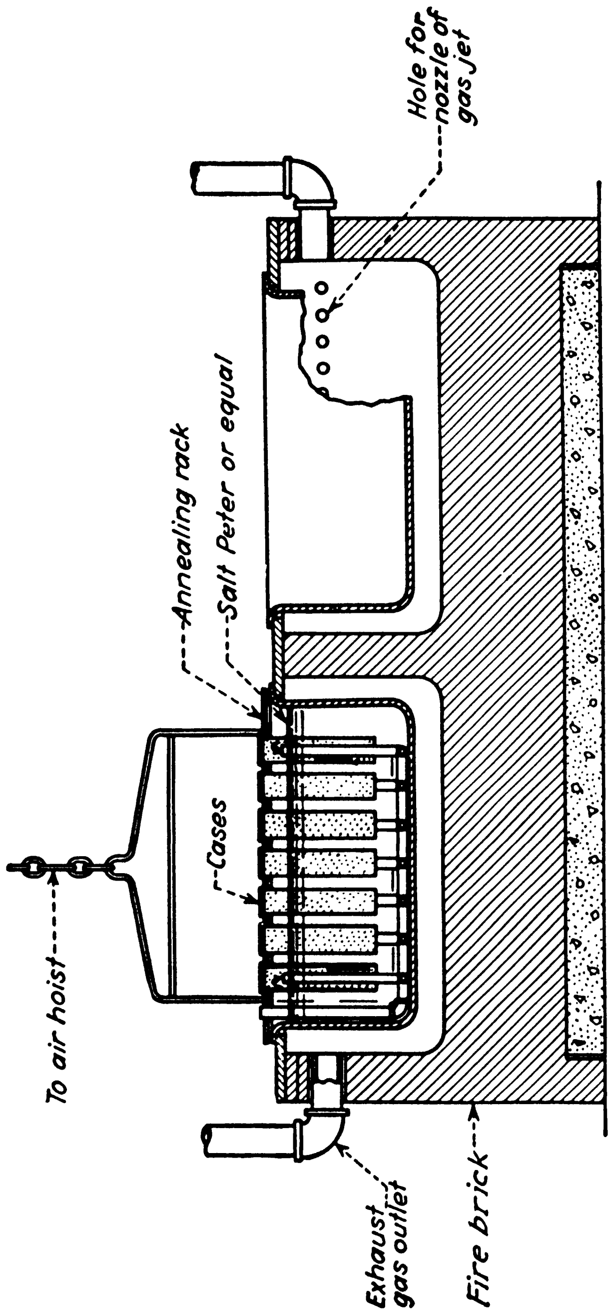


FIG. 350.—Since the head of the shells are closed, a special arrangement for venting is required in the body-annealing furnace.

that no cold shuts or folds are present on the inside radius of the case that might cause separation of the head from the side wall during service. Dimensions appear in Fig. 349.

Following this operation, the cases are ready for body annealing to help ease the tapering operation without caving in the side wall. The cases are placed in an annealing rack and submersed, mouth down, into molten saltpeter (potassium nitrate), at a temperature of 950°F. to a depth of 9 in. They remain in this bath for 1¾ min.

Since no hole is provided for the escape of air as the cases are immersed in this bath, an air vent fixture was made as shown in Fig. 350. Immediately upon completion of this anneal, the work is raised by an air hoist and plunged into a cold-water bath in order to remove the molten saltpeter. The cases are finally rinsed in hot water to aid drying just prior to the tapering operation.

Tapering Artillery Shells.—For the tapering operation, the side wall is lubricated with a combination of 25 per cent soluble and 75 per cent lard oil. Each case is then placed mouth down in the die of a six-station dial-feed mechanical press and indexed under the bumper, or punch, automatically. It is forced into the die as shown in Fig. 351 and tapered to the final dimensions of the finished case as seen in Fig. 352.

Each case is stripped from the die by a rocker arm at the bottom of the press, which extends from the work station to the ejecting station. This operation requires approximately 20 tons and a ram speed of approximately 60 ft. per minute.

After the cases are tapered, they are ready for the final machining of the head and primer hole. This operation is done on a four-spindle horizontal chucking machine.

When the head and primer hole have been finished in the chucking machine, the cases are trimmed at their mouths on a two-spindle drill press. The final trimmed size is 13.82 minus 0.04 in. over all.

The cases are then washed in an alkaline cleaner to remove the grease and oil accumulated from tapering and machining operations. This is done to prevent unnecessary stains on the finished case when mouth annealed.

The final mouth anneal is carried on in the same manner as the anneal for tapering, with the exception that the cases are immersed at the mouth 2⅛ in. for 2½ min. The air vent is unnecessary as the cases have the primer hole in the head of the case. At the completion of this anneal they are submerged in a cold-water tank, then in an alkaline cleaner, and rinsed off in hot water to dry. The annealing operation is done to make the metal at the mouth ductile enough to

prevent setting up excessive strains in the metal that would cause cracking after the projectile is inserted and the complete "round" placed in storage.

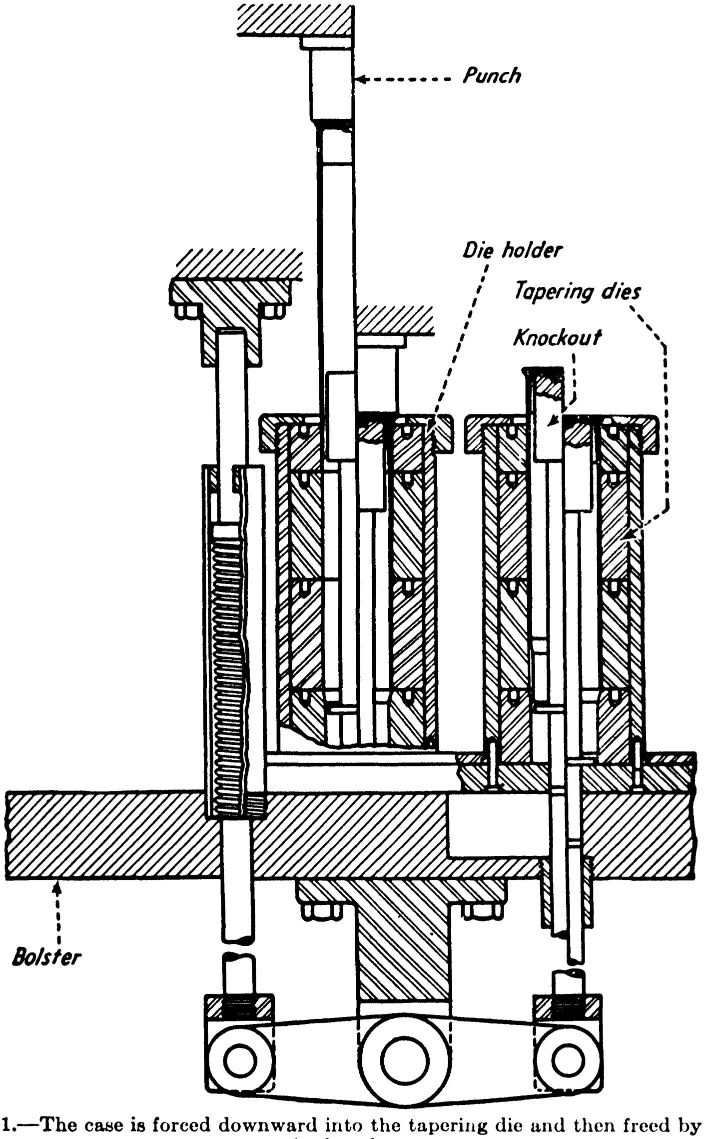


FIG. 351.—The case is forced downward into the tapering die and then freed by means of a knockout.

Following this operation, the cases are ready for the stress-relief anneal. A conveyer-type furnace is used for this operation, the cases

being charged at one end of the furnace and discharged at the other end.

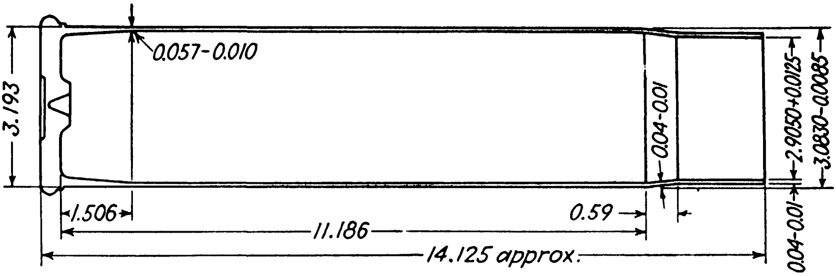


FIG. 352. Dimensions of the case after the tapering operation.

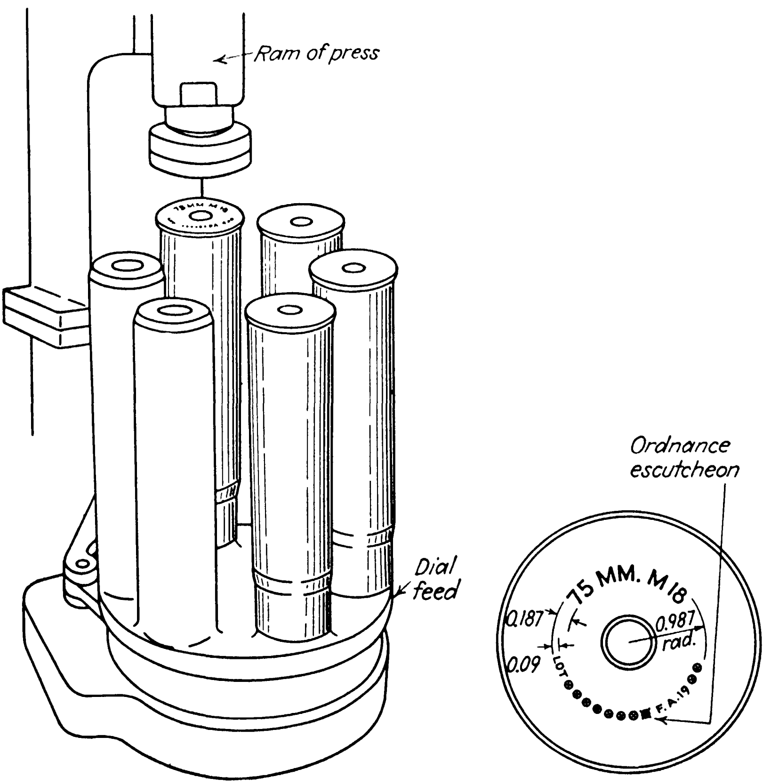


FIG. 353.—Cases are stamped in a dial-feed press for the final operation before packing.

The cases are stored on trucks to be cooled and are then ready for inspection. At the completion of inspection, they are stamped

in a dial-feed die similar to the one shown in Fig. 353 and then packed ready for shipment.*

DRAWING 105-MM. "M-14" HOWITZER BRASS CARTRIDGE CASES†

Die Operations Producing 105-mm. Cartridge Cases.—The production of artillery cartridge cases involves a series of progressive redraw-

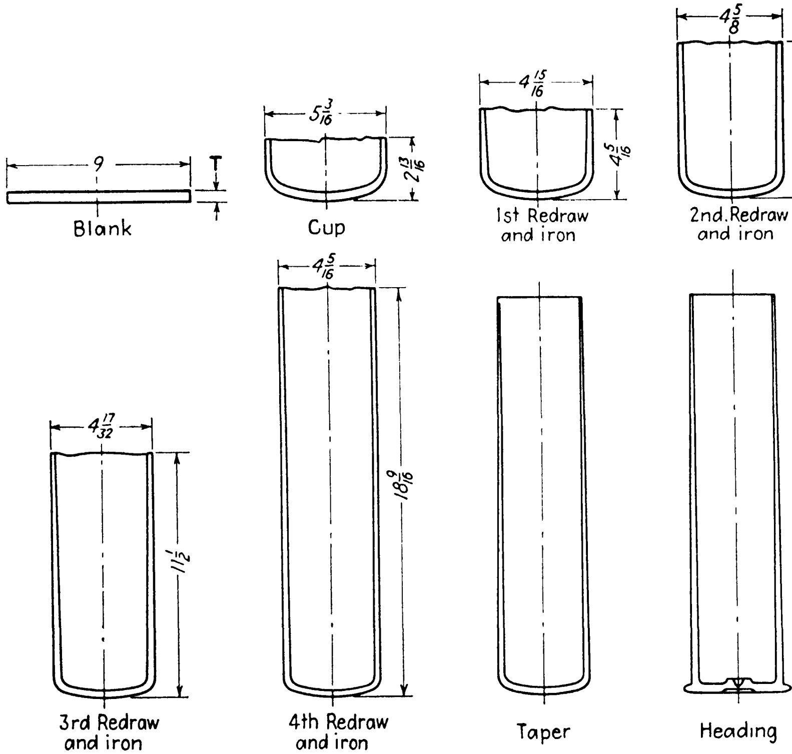


FIG. 354.—Sequence of die operations for producing 105-mm. brass cartridge cases.

ing operations. Starting with a flat disk of cartridge-case brass, the first pressing operation forms the disk into a cup. This cup is then redrawn four times until the proper depth and section are obtained, as shown in Fig. 354.

When cupping or drawing, the case is "pushed through" the draw ring in the lower die by the punch fastened to the moving press slide. The return upward movement of the press slide strips the case from

* For reproduced photographs showing circular dial-feed presses set up ready for drawing cartridge cases, and further descriptions, see Fig. 137, p. 186. For a photograph of a modern hydraulic heading press and description, see Fig. 309, p. 371.

† *Bulletin* 34, issued by (H-P-M) The Hydraulic Press Mfg. Co.

the punch. Each press has a cored hole in the press bed, permitting the cases to be ejected through the bed. Wire-type conveyer tubes connect the bottom of each press with a washing tank located directly behind. At every press cycle, a case is forced into the washing tank. This is accomplished automatically without manual or mechanical aid and without any damage to the case. The case must be washed after each drawing operation to remove drawing compound. After washing, the case must be furnace annealed to relieve stresses caused by the drawing operation. After the cases are annealed, they are pickled to remove scale caused by the heating.

The method of case handling employed is called the "batch" process. After washing, cases are placed in steel baskets and started through a continuous furnace. As soon as the cases are removed from the furnace, they are transferred to wooden baskets, then submerged in pickling tanks. A manually operated electric hoist handles the baskets during the pickling process. After the scale has been removed from the cases, the baskets are emptied and the cases are stacked in suitable bins and delivered by electric truck to the next drawing press.

After the fourth draw, the cases are trimmed to a uniform length. The closed end of the case is then ready to be headed and indented. This is accomplished in one operation by a hydraulic heading press. After heading, the cases are transferred to an H-P-M tapering press, which tapers the open end of the case so that it will fit around the projectile and also fit the breech of a gun.

The sequence of press and die operations, drawing-die designs, and the equipment used for annealing, baths, washings, pickle, and rinsings are very similar to those illustrated and described under Figs. 334 to 353 inclusive.

Drawing Steel Shell Cases.—A process has been developed recently for drawing and redrawing shell cases from sheet steel blanks. The experiments, conducted for several months, were successfully terminated late in 1942. This process will release many thousands of tons of copper-zinc alloys now used in the manufacture of shell cases and will reduce costs many millions of dollars. The discovery will, no doubt, be an outstanding one in the war.

Under the direction of Major General L. H. Campbell, Chief of Army Ordnance, Buick engineers have developed this new method for the mass production of steel shell cases in the larger calibers. This shell case is capable of withstanding high-pressure gunfire, is easy to load and eject from the gun chamber, has met all the required tests in both hot and cold guns, and is free from spark hazard and obturation.

Requiring no special steels or alloys of critical materials, or extra shop equipment, the process was developed by experimentation with dies of one-third size, and part of the process includes using a new system of cold-pressing and sizing. Drawing steel shell cases involves the chemical and metallurgical sciences more than tool engineering. For the 75-mm. steel shells there are forty-three operations, or more than twice the number used in producing brass cartridge cases. A detailed account of the several methods used, the chemical treatments, and tools employed was published in the Armament Section of *American Machinist*, May 13, 1943; Volume 87, No. 10.

Tremendous Trifles.—A pamphlet issued by the Office of War Information entitled "Army Ordnance Presents Tremendous Trifles" gives many suggestions for saving critical materials and for redesigning products to save tooling and machining time. This is valuable information for the tool engineer in times of war or peace. There is no saving by increasing our steel production three times if the enemy makes his steel go three times farther than ours.

This publication cites one particular situation in which 105-mm. cartridge cases were drawn from steel instead of brass. On one ordnance contract this conversion saved 12,600 tons of brass, and this is only a very small part of the total saving made possible by the changing of cartridge-case material from brass to steel.

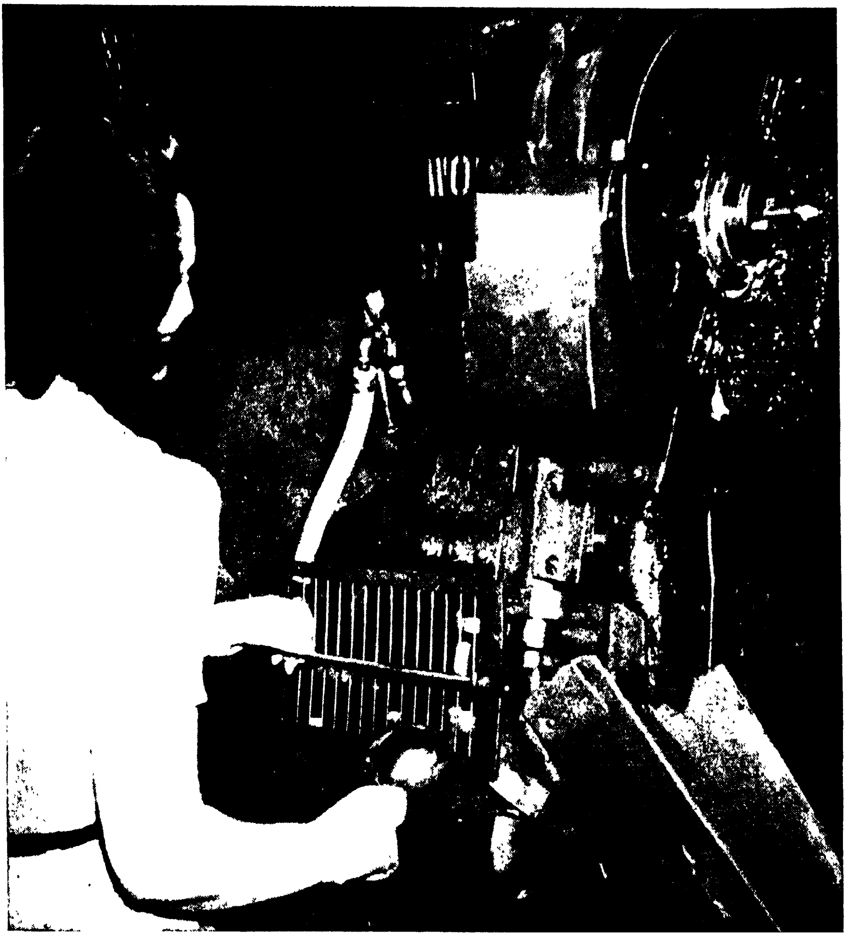


PLATE XI.—Women in war industry. This woman is turning out small stampings on a 10-ton press in the General Electric plant at Schenectady, N. Y. In her right hand she holds feeding tongs containing the next piece of metal to be inserted in the die. After the operation, the formed parts are automatically blown by compressed air into the chute at the right. The operator's left hand holds the safety guard in place; the press cannot be operated except when the guard fence is held down in the position shown. Notice the ventilated sheet metal guard surrounding the flywheel and the hinged door opening into it. (*Ewing Galloway photograph.*)

PLATE XII

Drop-hammer Operations

The workman in the picture on the opposite page is engaged in operating a drop-hammer press which forms aircraft parts in the Middle River Plant of the Glenn L. Martin Company, near Baltimore, Md. Drop hammers are used in forming shallow shapes of shells, retainers, stiffening ribs, etc. It is strictly an impact operation, and therefore is not practical where the workpiece requires an interval of time in which to "flow" into another shape.

The Martin plant is one of the largest and most modern in the world. It houses the largest assembly floor in the United States, 1,100,000 sq. ft. For test flights of Martin bombers, they have a 420-acre airport which is about the size of La Guardia Field in New York.

Here, more than 300 engineers and aeronautical scientists and 15,000 employees are engaged in turning out, at top speed, planes for the Allies and the United States air forces. Numerous improvements have been evolved to speed up production. For instance, experts noticed that, when a bombing plane nose passed through the assembly line in one piece, only two or three men could work inside it. Now the nose is sent down the line in two halves, in each of which three workmen can operate with ease.

So rapidly is production moving today at the Martin plant, that the company has opened a training school for men just out of colleges and technical schools, to fit them for the new positions that are constantly arising.

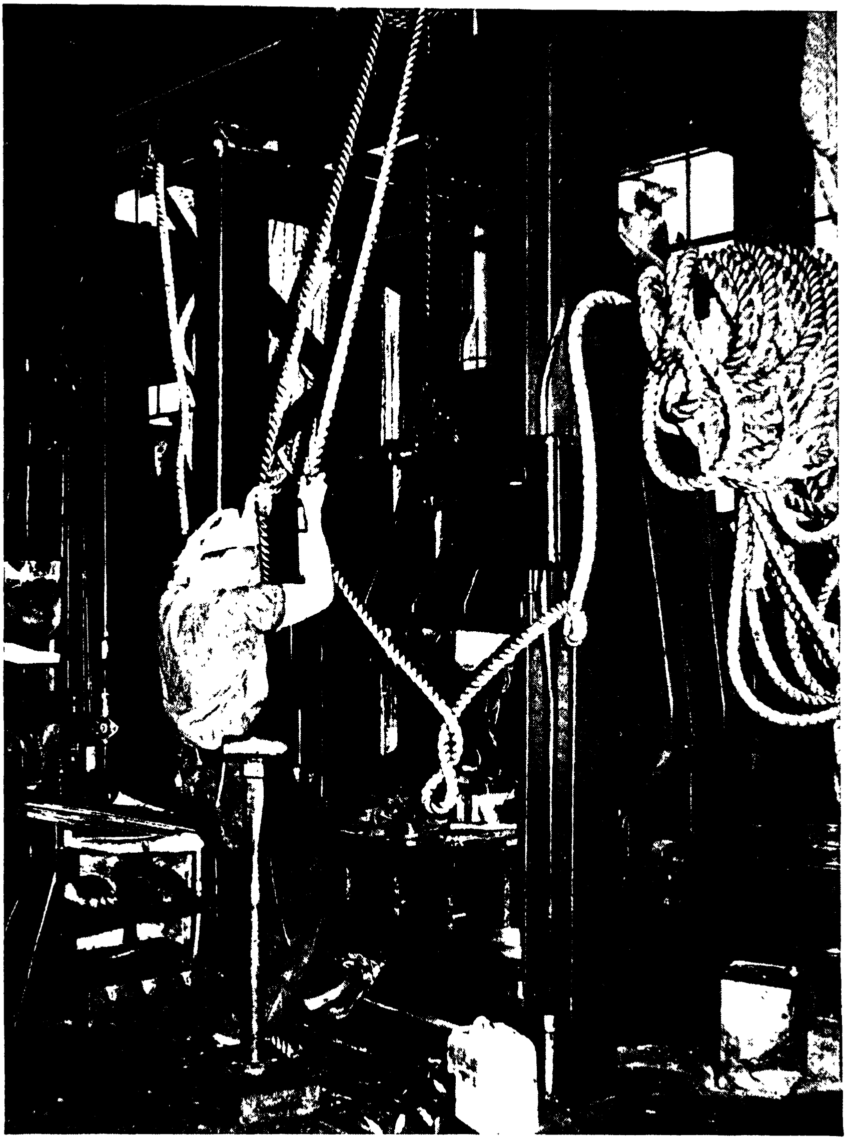


PLATE XII.—Drop-hammer press in operation. Operating a powerful drop-hammer press that stamps and forms airplane parts to size and shape. Hand tension on the rope tightens its coils around a revolving drum above the press and lifts the heavy hammer. Loosening the coils, when the hammer is high enough, permits it to drop with its attached punch or die and to form the blank that has been placed over a corresponding punch or die on the stationary bed of the press. In some drop-hammer presses the hammer is lifted by an electric motor. (*Acme photograph.*)

PLATE XIII

The Use of Drop Hammers

The picture on the opposite page shows a toolmaker polishing the faces of a drop-hammer die. Attention is directed to the wooden master pattern shown at the top of the picture. This model is surfaced with Prussian blue. It is lowered on the die occasionally to impress blue marks on the high spots of the die, showing where additional grinding and polishing must be done.

Drop hammers are used for producing stampings in which the impact type of blow is more applicable than the relatively slower action of the punch in crank presses. In addition, drop hammers are used for secondary operations such as restriking stampings that have been drawn or partially formed in crank presses or for operations similar in principle to coining.

Many types of bending operations, such as the forming of extrusions and similar work, can be more successfully accomplished in drop-hammer presses than in crank presses and in some cases better than in bending machines. By using an impact blow, "spring-back" in the work is reduced to a minimum. In crank presses, spring-back variations in the work are very troublesome, especially with hard metals.

Drop-hammer dies are made from zinc, and from an alloy known as "Kirksite," which can be obtained from the National Lead Company. Cast iron is sometimes used, but the nature of the workpiece largely determines the use of the latter. The forming operations are not limited to the use of aluminum alloy. Stainless steel, can also be successfully formed in drop-hammer presses. For ordinary steel and Stainless steels, annealing operations by means of an acetylene torch are sometimes necessary in forming extremely difficult shapes.

PLATE XIII.—Toolmaker at work finishing a composition die. Polishing the faces of a drop-hammer die to be used in forming an aluminum-alloy aircraft cowling. (*Courtesy of Curtiss-Wright Corporation.*)

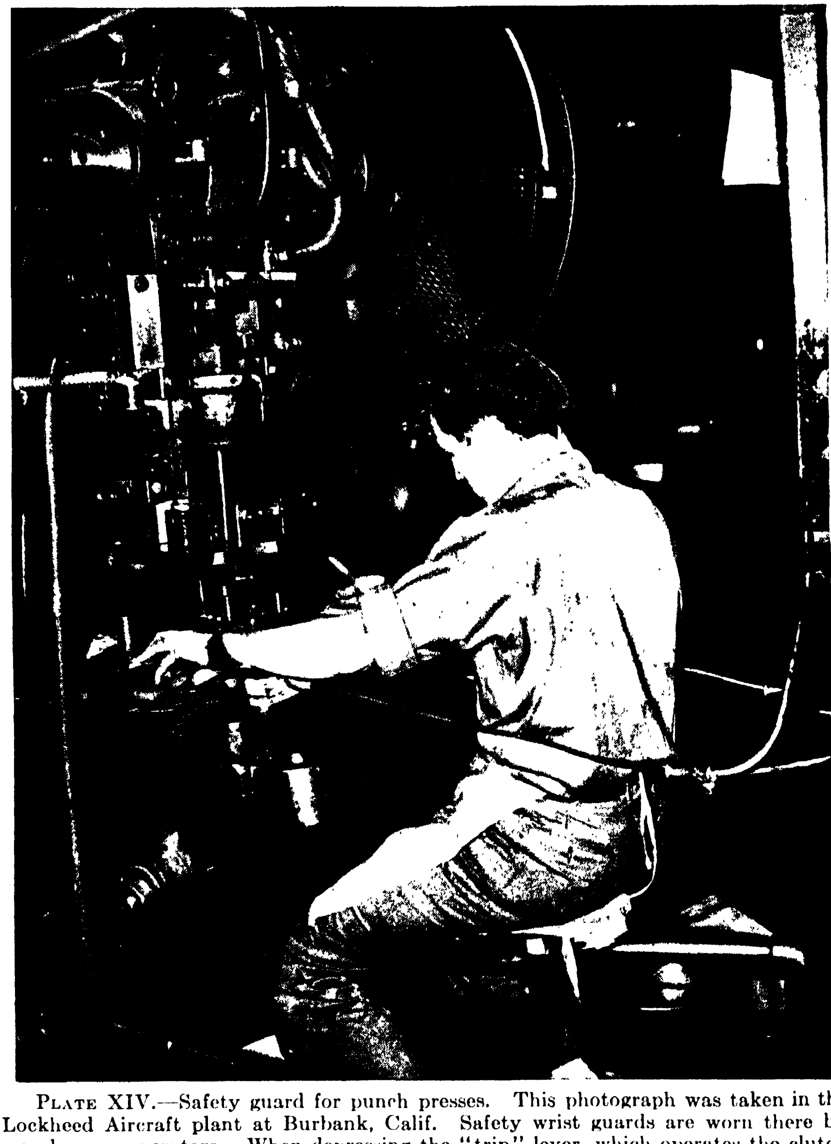


PLATE XIV.—Safety guard for punch presses. This photograph was taken in the Lockheed Aircraft plant at Burbank, Calif. Safety wrist guards are worn there by punch-press operators. When depressing the "trip" lever, which operates the clutch and press, the guards automatically withdraw the workman's hands from the danger zone under the punches. (*Acme photograph.*)

PLATE XV.—Toolmaker at work finishing a composition die. This picture shows a toolmaker grinding and fitting a punch and die for a forming operation involving an extreme bend. In this case the work is sheet-aluminum alloy. (*Courtesy of Curtiss-Wright Corporation.*)

PLATE XVI

Shallow Parts Formed in Drop Hammers

On the opposite page is an illustration of a moderate forming operation for a piece of airplane cowling. The depth of draw here is too moderate for the conventional type of crank-press draw die. If a drop-hammer die may develop wrinkles in the work, a heavy rubber pad is used for the preliminary striking operation, forcing the metal to "flow" into the correct pattern. The rubber is then removed and the work is restruck to the final shape.

PLATE XVI.—Forming and sizing parts for airplanes. Drop-hammer die that forms a shallow shape for a piece of aircraft cowling. The operator is inspecting the finished work before removing it from the die. (*Courtesy of Curtiss-Wright Corporation.*)

PLATE XVII.—Forming by arranging rubber pads. Illustration of a preliminary forming operation on a Stainless-steel part that involves a warped surface. This piece could not be successfully drawn in a crank press. As in Plate XVI, the rubber pads are removed before the final strike is made. This punch and die are set up in a hydraulic press. (*Courtesy of Curtiss-Wright Corporation.*)

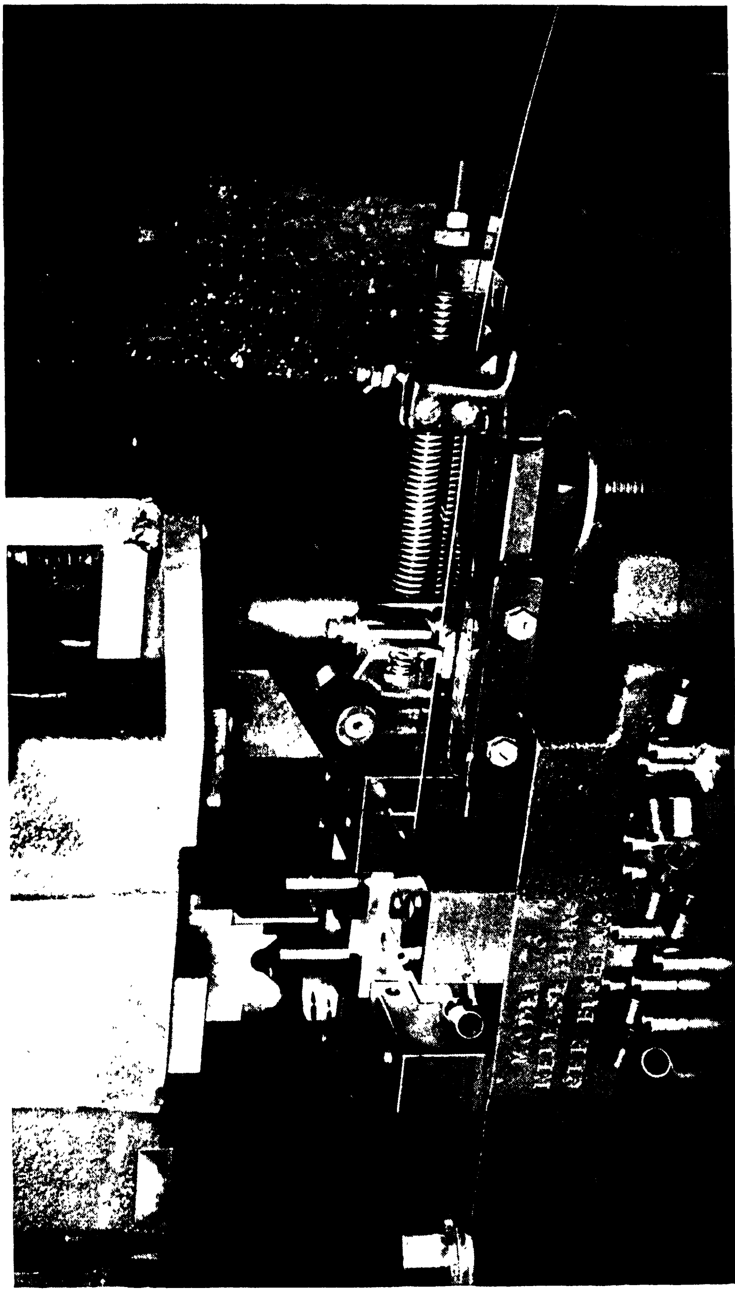


Plate XVIII.—Automatic feed for progressive dies. A Dickerman "hitch feed" shown attached on the right end of the die shoe in a press tool set up on an inclinable gap-frame press. This attachment automatically feeds light strips up to 8 in. wide onto blanking centers 4 in. long, or less. A detailed description of this feeder is given on page 186.

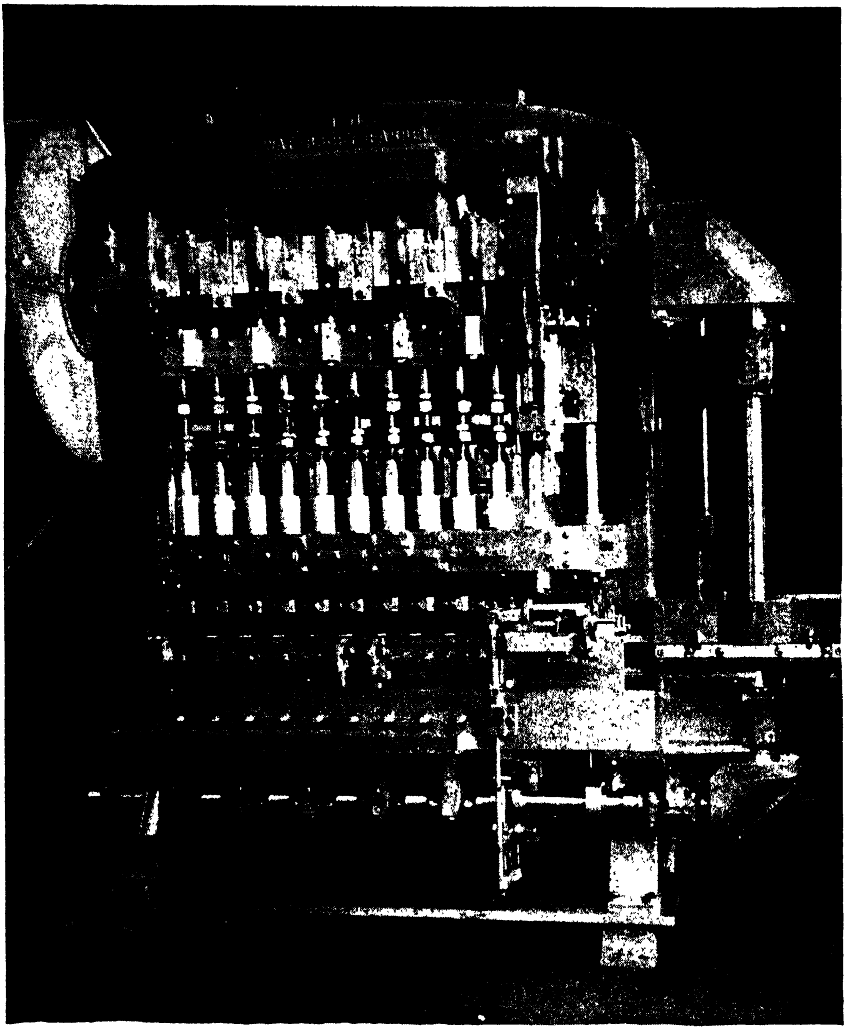


PLATE XIX.—Multiple-plunger eyelet machine. A typical eyelet-forming machine for blanking and redrawing small shells in great quantities from light gages of strip. In next to the last station at the left, the shell body can be sized, and, if an annular rim is required, it can be trimmed in the last station and the shell pushed out through the die.

PLATE XX.—One press stroke forms many different airplane parts. These press operators are locating Duralumin blanks of many shapes over pilot pins in punch and die tools. The tools are arranged on a movable plate, which is then shoved under the platen of confined rubber in a large hydraulic press. When the platen descends upon the blanks, the pressure of the rubber forms them over the dies, which are of the various shapes required in aircraft assemblies. (*Cleared by the War Department for Lockheed Aircraft Corporation.*)

PLATE XXI.—Forming streamlined parts by drop hammers. Inspecting a Duralumin part that has just been formed in a drop-hammer punch and die; the withdrawn punch is shown in the foreground. The part is a piece of fairing which is a unit in streamlining parts of the fuselage in Vega bombers. (*Cleared by the War Department for Lockheed Aircraft Corporation.*)

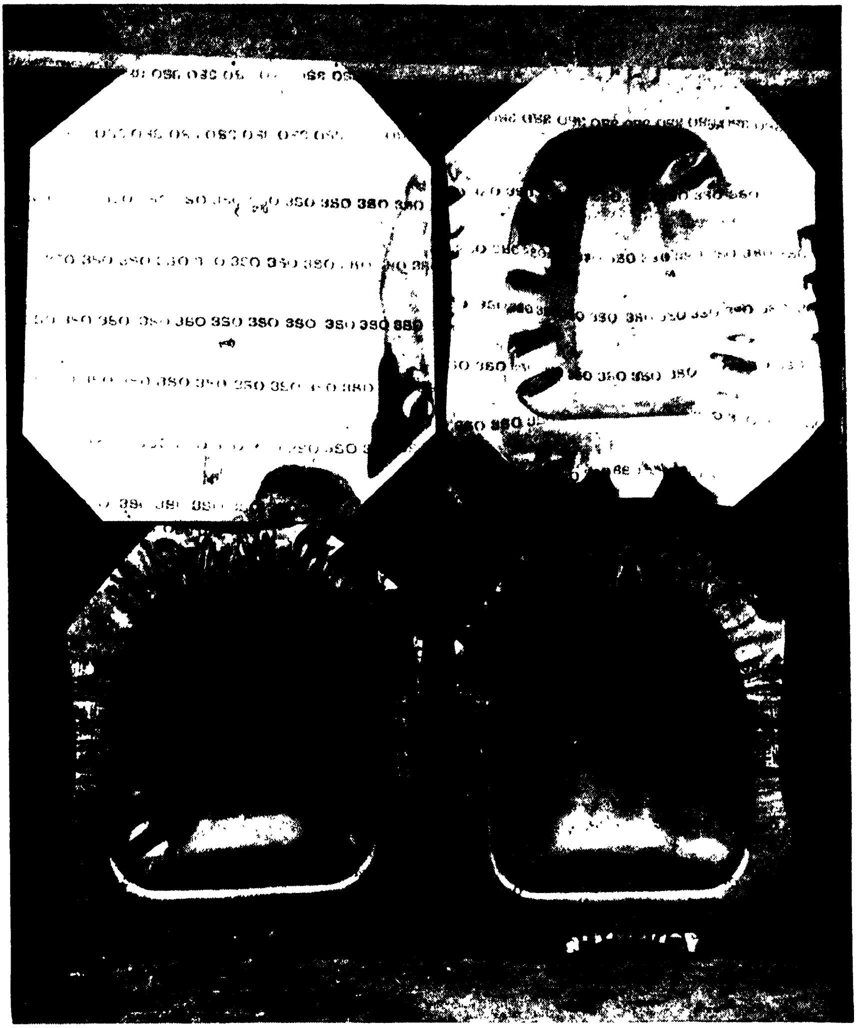


PLATE XXII.—Aircraft parts drawn in drop-hammer dies using plywood panels, showing the blank and three stages in deep drawing of Duralumin parts in a drop-hammer die. The successive depths of draws are spaced by using ordinary three-ply wood panels which are placed around the work under the flange. The plywood pieces are removed one at a time after each of the successive draws has been made. The part being made here is the beginning of an air scoop for an oil radiator used in a Lockheed Model-10 small transport plane. These planes are sometimes converted into light attack planes. The letters "3SO" shown across the blank and work indicate an arbitrary third degree of hardness for soft aluminum. (*Cleared by the War Department for Lockheed Aircraft Corporation.*)

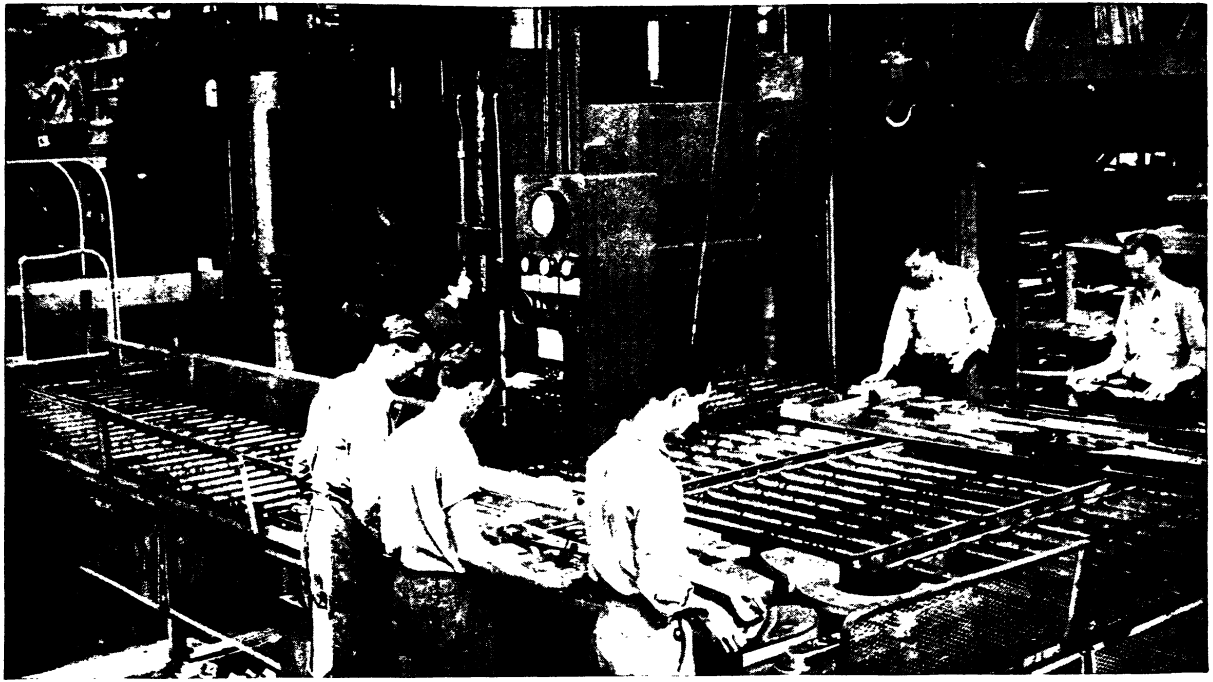


PLATE XXIII.—Forming many small parts in one press stroke. A huge Watson-Stillman hydropress fabricates small parts from Duralumin blanks in the Lockheed Aircraft plant at Burbank, Calif. The parts made are used in both the P-38 lightning fighters and the Hudson medium-sized bombers. The feature here is the "merry-go-round" table equipped with roller conveyers, on which forming dies, with blanks placed on them, are transported under the rubber platen in the press for forming, after which the finished parts are removed by the crew. (*Cleared by the War Department for Lockheed Aircraft Corporation.*)

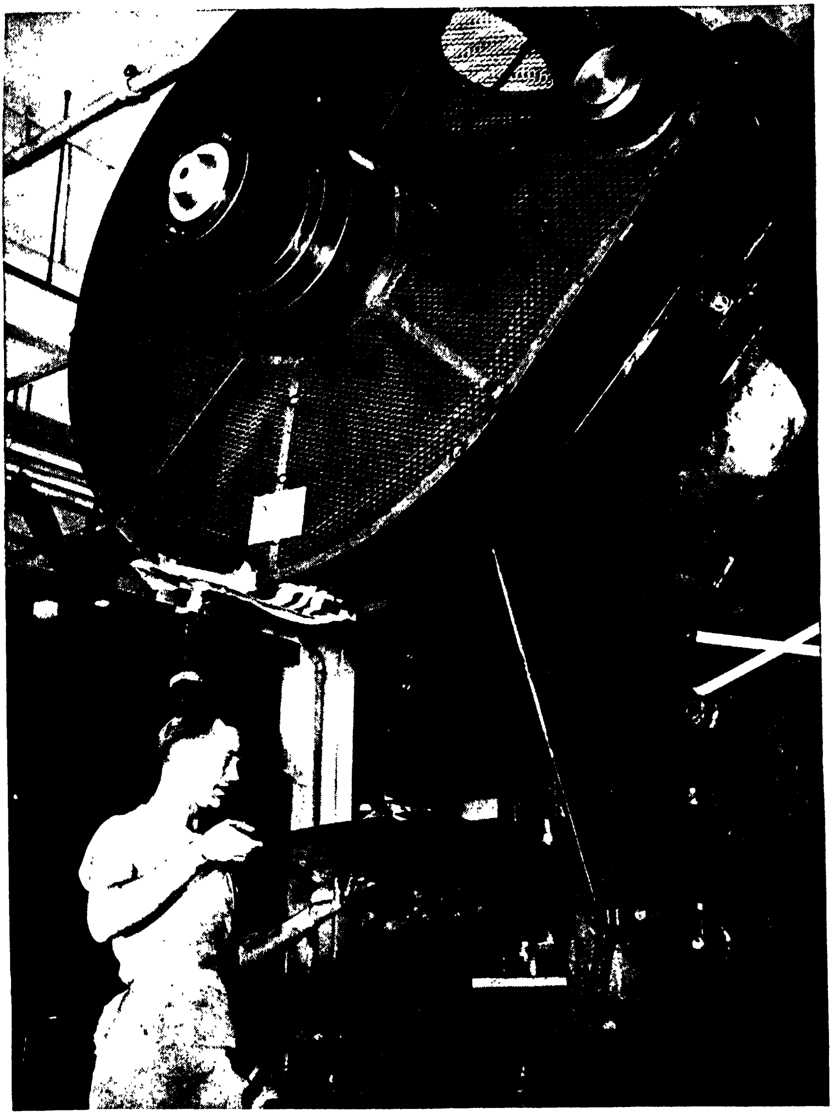


PLATE XXIV.—Preparing the blanks to be subsequently formed in hydropresses. A high-speed crank-driven motor-drive press set up with punches and dies for cutting blanks and piercing holes in the parts formed in Plates XX and XXIII. (*Cleared by the War Department for Lockheed Aircraft Corporation.*)

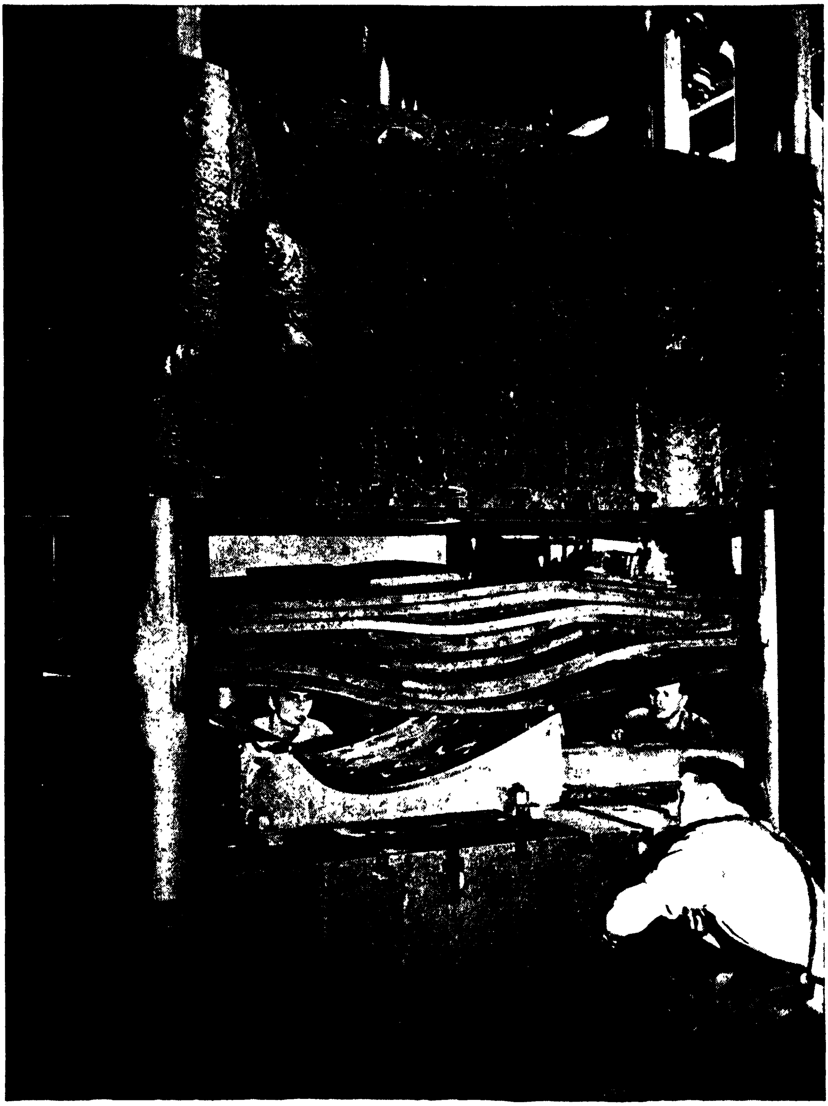


PLATE XXV.—Forming parts by using extra rubber mats. Expert press operators placing and inspecting the positions of rubber pads used for pressing and shaping sheet Duralumin blanks over a forming die anchored on the bed of a hydraulic press. These men must be experienced in knowing where and how to place the pads to get best results when shaping parts that are formed in different dies. (*Cleared by the War Department for Lockheed Aircraft Corporation.*)

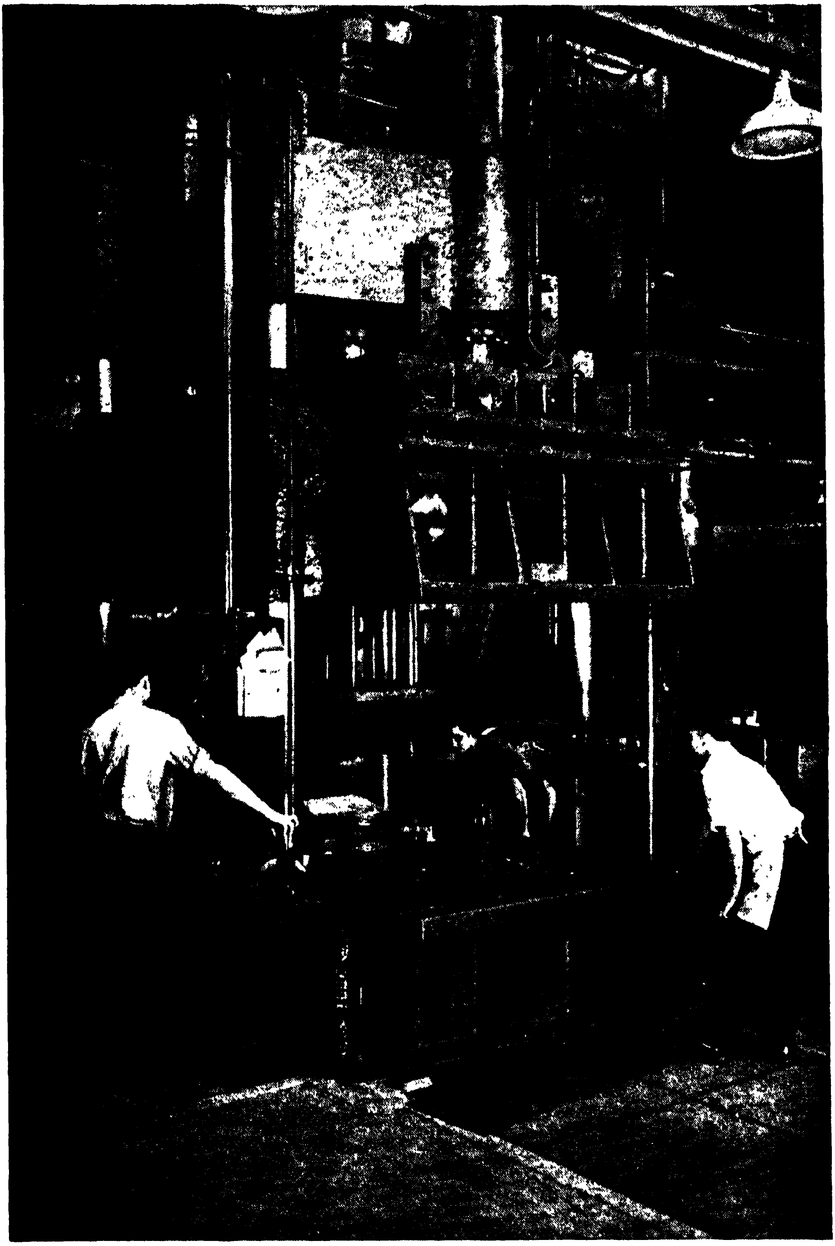


PLATE XXVI.—A double-action hydropress. A hydropress having a built-in double-action feature is shown drawing deep parts of Duralumin sheet for P-38 lightning fighters and Hudson bombing planes. With this equipment a series of deep draws can be made in one closing of the press. (*Cleared by the War Department for Lockheed Aircraft Corporation.*)

PLATE XXVII

Phototemplates Speed Production

Lockheed Aircraft Corporation has put photography to work on the production line. Engineers' drawings are transformed to foolproof working shop patterns in a few hours. The accurate metal patterns produced by the photographic-template process effect great savings in time between the completion of engineers' drawings and the start of actual production.

A finished template is turned out in from 4 to 8 hr. It eliminates the long checking time, sometimes as much as 250 hr., that was necessary under the old methods.

Engineers and detail layout men make full-size drawings on painted sheet metal. The drawings are then photographed on glass plates. The glass negative is then used to reproduce the original on sensitized sheet metal, which is developed, "hypoed," washed, and dried like any other print.

The finished print on metal is the template. From it may be cut as many identical parts as there are planes to be built on order. It is a foolproof pattern, carrying information and instructions down to the last bolt-hole location, permanently printed on metal.

It is accurate: the allowable tolerance of limits is but 0.001 in. per foot, and the template shows everything that was on the original engineers' drawings.

This system uses Eastman priming and developing solutions. The above information was furnished by G. T. Allen of Lockheed Aircraft Corporation, Burbank, Calif.

PLATE XXVII.—An expert in Lockheed's plaster "mock-up" department checking contours on a large section of an airplane made in plaster from phototemplates. Later, this plaster form will be cut into workable sections and the parts used as patterns for casting hydropress and drop-hammer punches and dies molded from Kirksite "A." *(Cleared by the War Department for Lockheed Aircraft Corporation.)*

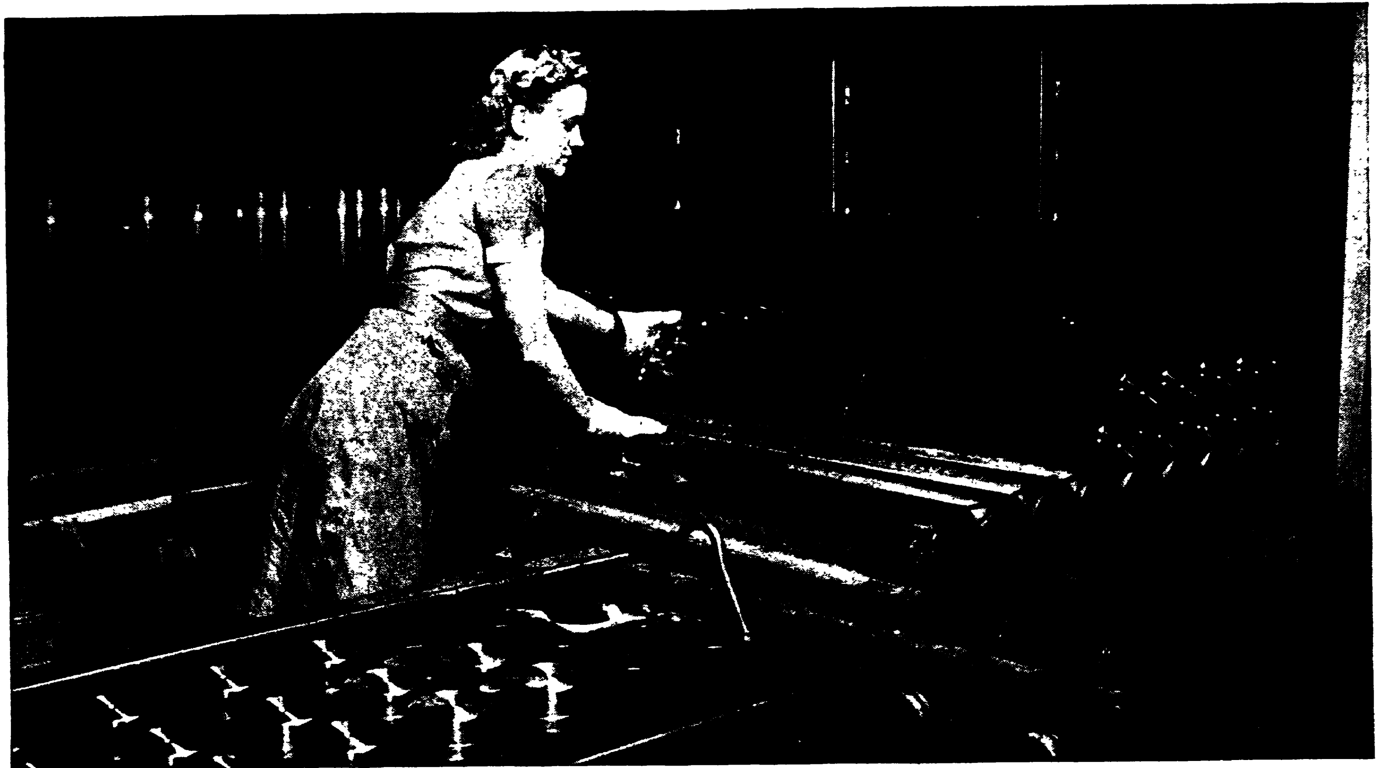


PLATE XXVIII.—Annealing cartridge cases. Placing 3-in. anti-aircraft cartridge cases into V pockets of an endless-chain carrier which transports them through an annealing furnace that makes them uniformly soft and ductile and ready for succeeding redrawing operations. Further details and descriptions are given on pages 402, 403, 409. (*O.E.M. photograph by Palmer.*)

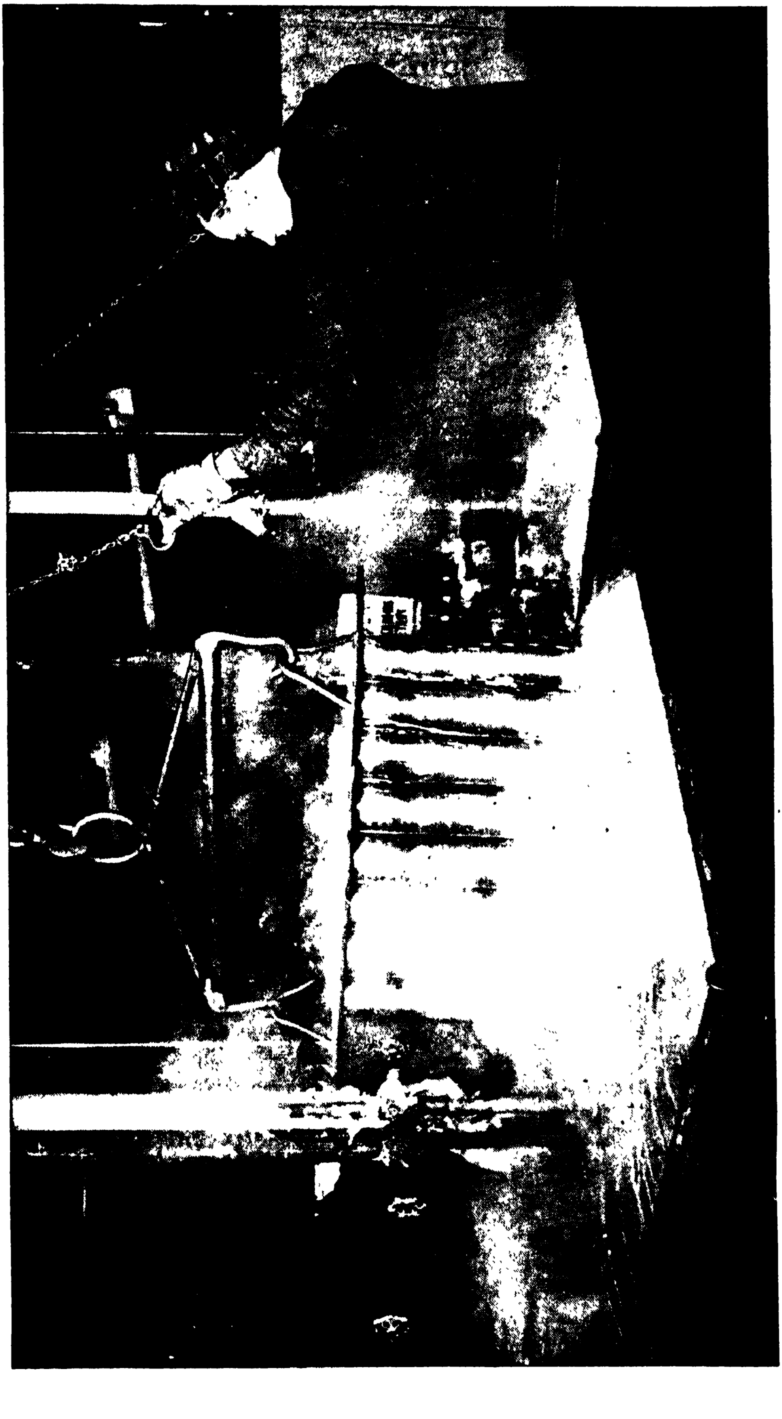


PLATE XXIX.—Special washing equipment used for cartridge cases. Washing 3-in. anti-aircraft cartridge cases after annealing, as described in the series of shell-drawing operations on pages 403, 409, 413. (*O.E.M. photograph by Palmer.*)

PLATE XXX.—Rough-trimming cartridge cases. An intermediate rough trimming of the open ends of 3-in. anti-aircraft cartridge cases before annealing, washing, pickling, and subsequent redrawing operations, as explained on pages 406, 413. (*O.E.M. photograph by Palmer.*)

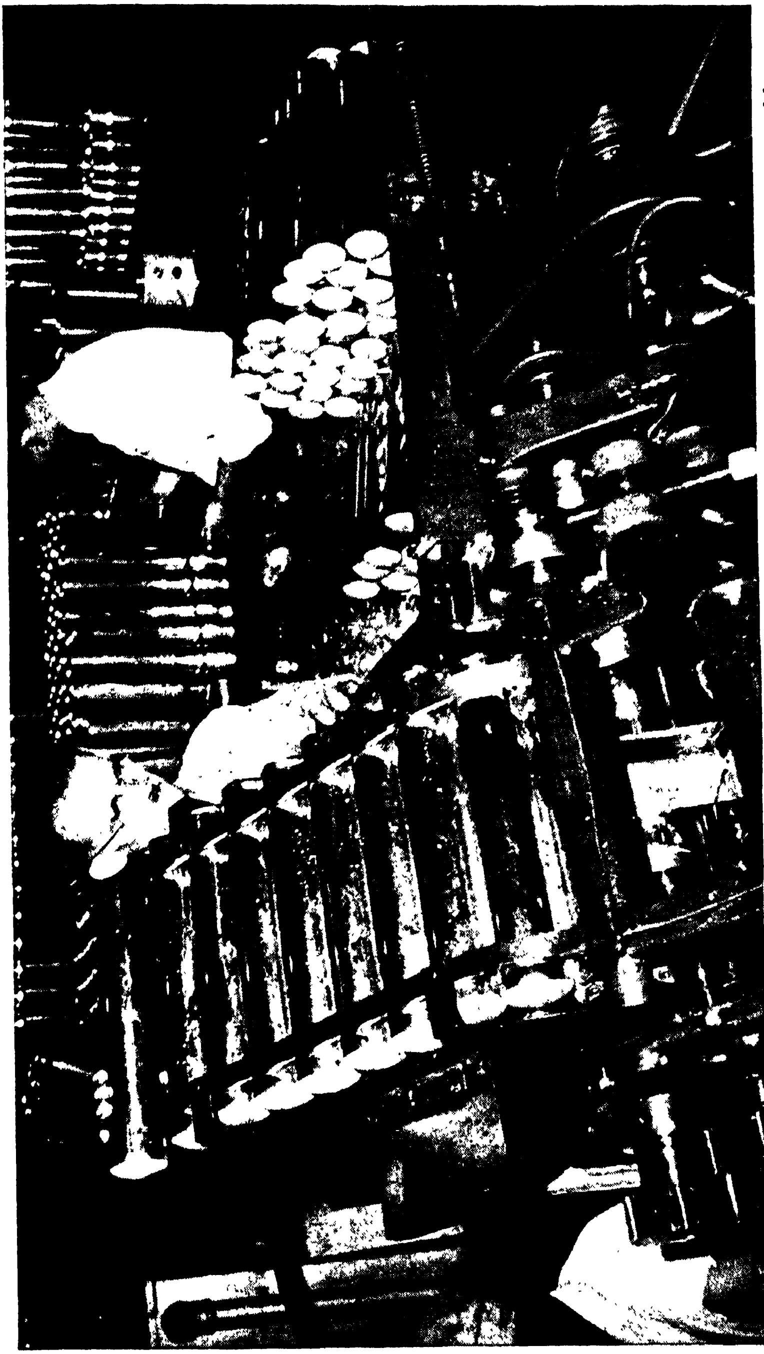


Plate XXXI.—Machine for trimming cartridge cases. Seventy-five-millimeter cartridge cases being trimmed between redraws in the production line at Frankford Arsenal, Philadelphia. This is a photograph of the machine sketched in Fig. 344, page 405. (*O.E.M. photograph by Palmer.*)

PLATE XXXII

A New Type of Drawing Press

A vertical section through a Misfeldt progressive drawing press, in which the die is positively mounted on a vertical hydraulic ram situated in the bed of the press. The die is automatically elevated a small predetermined distance each time the punch ascends. On the downstroke, the lower ram and die is locked in position. As a result, each stroke of the punch enters a little deeper into the die. This causes the work material to be drawn slightly beyond its yield point and in short progressive stages of uniform depths.

However, the press can be adjusted to draw the metal only within the range of its elastic limit, thus entirely eliminating thinning of the metal walls in the shell being drawn. This feature introduces a new principle in deep drawing of shells, in which the shape of the shell is established because of a slight shrinking of a portion of the work material between the pressure plates while the punch is drawing it into the die. A series of short progressive draws permits the metal to take on its new shape without tearing or fracturing the shells.

If the work material is light-gage sheet, the drawing stages may be only $\frac{1}{16}$ in. deep. Short draws have a tendency to force the metal into plastic flow and to shrink rather than to stretch. This condition causes the shell to rearrange itself and to hug around the punch contour as desired. When drawing heavy-gage shells, each of the progressive drawing stages can be made deeper than $\frac{1}{16}$ in., but at no time is it necessary to stress the metal to a point where the shell shows the well-known "orange-peel" appearance. This appearance indicates thinned walls and is a common fault when drawing and forming work by drop-hammer strokes and in conventional crank presses.

This reproduced photograph also shows the perfectly controlled blankholder used in these progressive presses. It is attached by pistons above the pressure plate of the blankholder itself, but is actuated and controlled by the movements of the hydraulic bed. By this simple arrangement, the blankholder is always "in touch" with the position of the die. Therefore, it maintains a uniform pressure on the material being drawn at each stage of the operation.

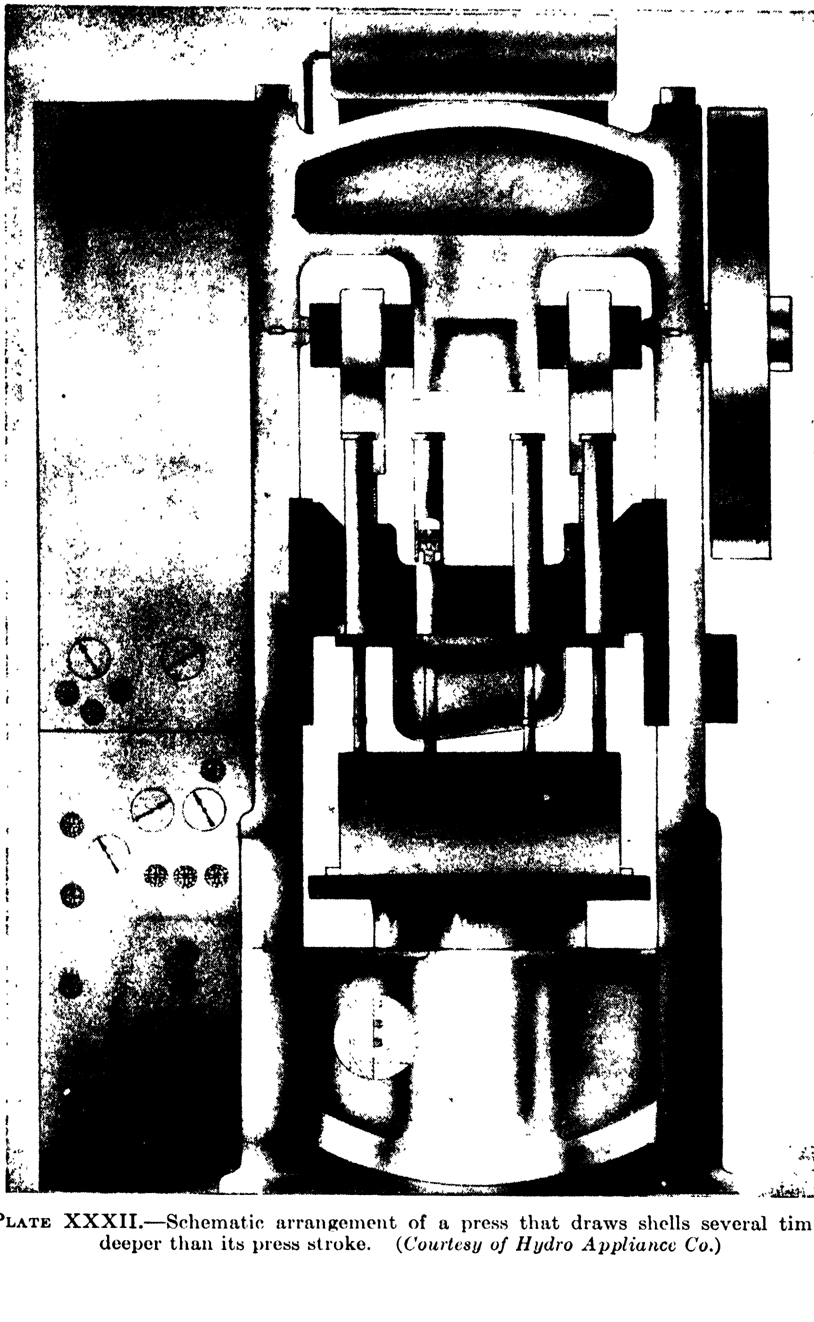


PLATE XXXII.—Schematic arrangement of a press that draws shells several times deeper than its press stroke. (*Courtesy of Hydro Appliance Co.*)

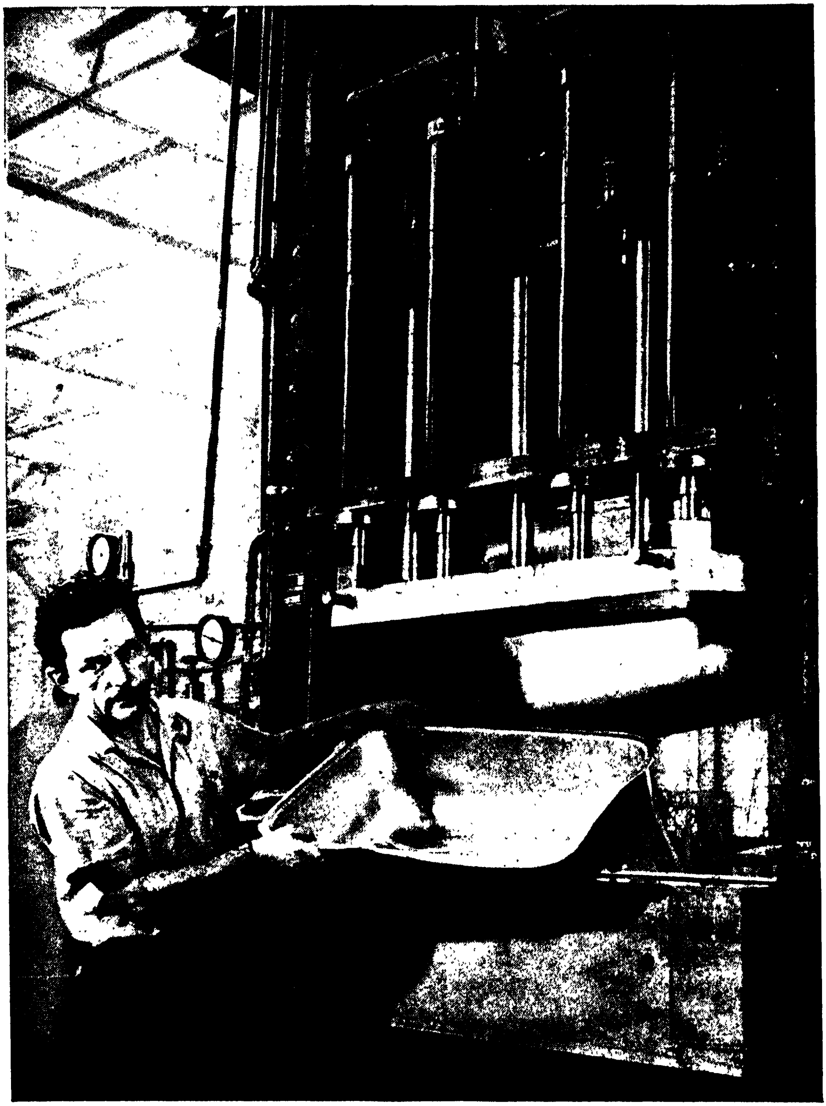


PLATE XXXIII.—Drawing the section of an oil tank. Showing Misfeldt progressive drawing equipment installed in a Bliss Standard 2-in.-stroke press. The work being drawn is an oil-tank section used in airplanes. Note the extreme depth of draw and the difference in depths at opposite ends of the tank. Light-gage aluminum-alloy parts can be drawn to depths of 16 in. on a 2-in.-stroke press, using these progressive operations. The schematic arrangement of bolster and pressure-pad cylinders is shown in Plate XXXII. (*Courtesy of Hydro Appliance Co.*)

PLATE XXXIV.—Manufacturing oxygen cylinders for airplanes. This picture shows the steel half domes for shatterproof oxygen cylinders that have been drawn in a hydraulic press with a die similar to the one shown in Plate III, page 254. The open ends of two of the domes are welded (see Plate XXXV) into a unit oxygen cylinder and finally assembled into warplanes. The cylinders are used for storing oxygen for high-altitude flying. (*O.E.M. photograph by Palmer.*)

PLATE XXXV.—Manufacturing oxygen cylinders for airplanes. Before the final welding operation is completed, all the reinforcement straps are subjected to rigid physical tests to determine the strength of the weld. Occasionally, radiographic tests are made to ensure the quality of workmanship and the materials. After the straps have been tested, the two halves of the cylinders are brought together in this automatic welding machine and joined in one unit. In the photograph the operator has just completed the union and is ready to remove the completed cylinder from the machine. (*O.E.M. photograph by Palmer.*)

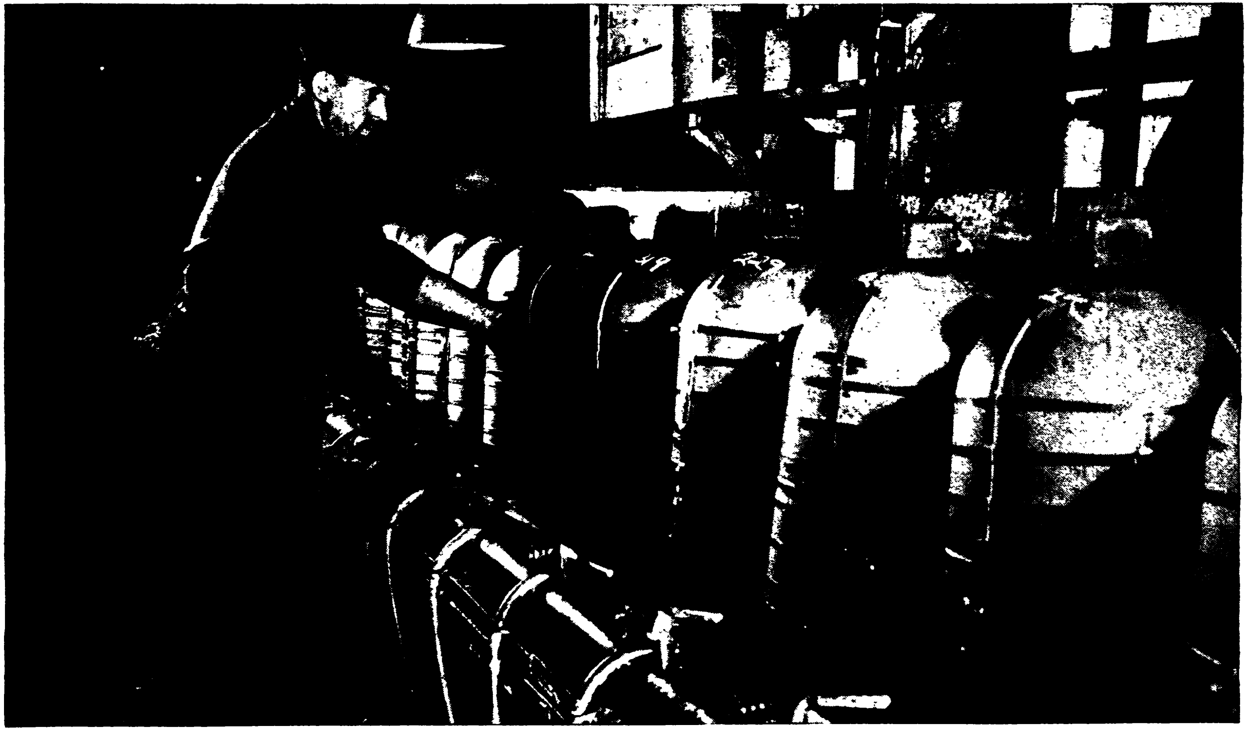


PLATE XXXVI.—Manufacturing oxygen cylinders for airplanes. After the two half domes have been welded together, all traces of scale must be removed from the interior to prevent contamination of the oxygen. This is done in the production line seen above. A special chemical cleaning solution forced through the cylinder at a controlled temperature "flushes" out all the foreign matter. (*O.E.M. photograph by Palmer.*)

PLATE XXXVII.—Manufacturing oxygen cylinders for airplanes. In the final operation each finished cylinder is subjected to high-pressure tests to ensure strength and safety. The first test is to introduce into the cylinder a hydrostatic pressure of 800 lb. per square inch or twice the pressure needed in normal use. This is a test for the strength of the welds. Next comes an airtight test in which a pressure of 400 lb. per square inch is introduced into the cylinder. In the picture the cylinder is being submerged in a steel tank filled with water to test it for air leaks. Using an attached crank, the inspector revolves the cylinder in the water to expose all surfaces while it is under air pressure. If it passes all the tests, this nonshatterable cylinder is then ready for assembly in a warplane to hold an oxygen supply for high-altitude flying. (*O.E.M. photograph by Palmer.*)

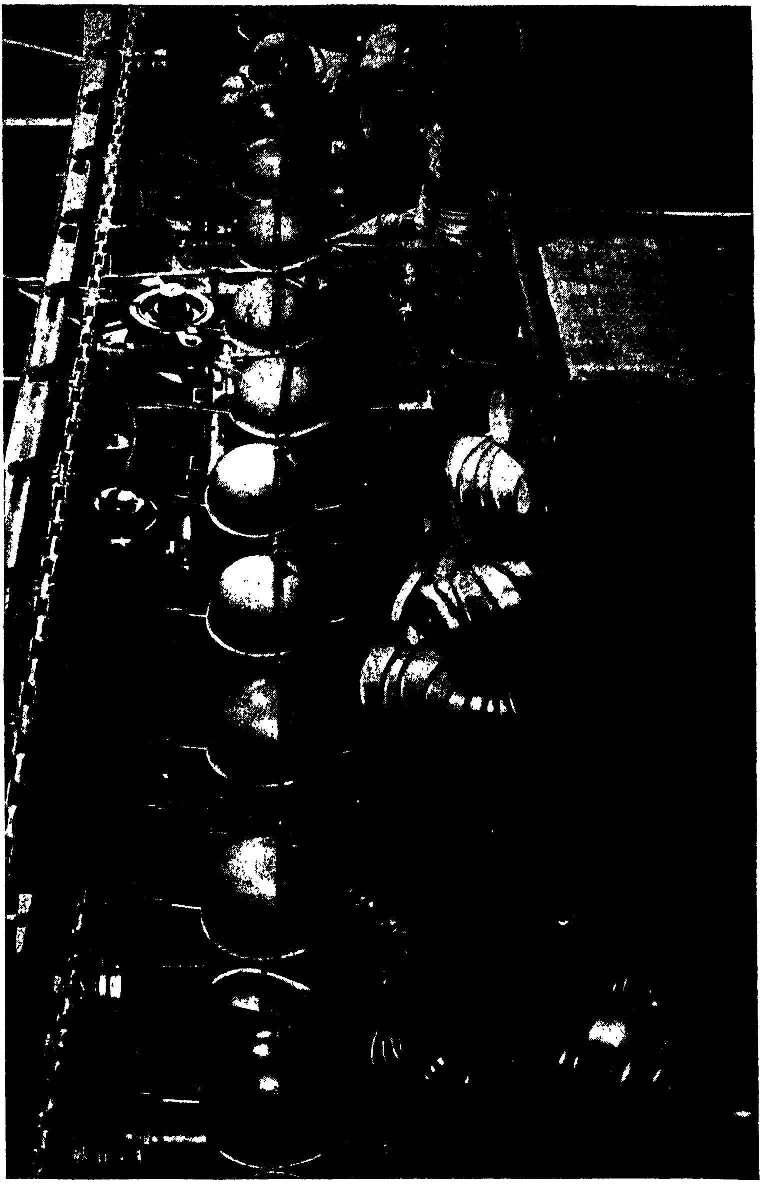


PLATE XXXVIII.—Manufacturing steel helmets for the army. This picture shows a monorail equipped with an endless-chain conveyer leading from the pressroom to the welding and finishing departments. After being drawn, formed, and trimmed, the helmets are carried along by the chain to other departments, where welding and finishing are done. (*O.W.I. photograph.*)

PLATE XXXIX.—Manufacturing steel helmets for the army. Electrospot-welding a reinforcement rim on steel helmets. This photograph was taken shortly after Pearl Harbor and shows the versatility of American industry. The man at the machine is an employee of an Eastern manufacturer whose peacetime product was radiators for automobiles. This workman formerly soldered radiator cores. (*O.W.I. photograph.*)

CHAPTER XVI

TABLES AND CHARTS

Press Capacities.—The tons capacity of a single-crank press is determined by squaring the diameter of the crankshaft in inches, taken at its main bearings, and multiplying the result by 3½ tons. This formula gives the conservative strength of a single crank in tons, but only up to and including a 6-in.-diameter shaft. It is advisable to select a press capacity in excess of the actual pressure required to do the work, at least 25 per cent higher. The formula given is for crankshafts having main bearings of equal diameters and located on each side of a single crank. The ultimate capacity is at the bottom of the crank stroke.

For double-crank presses the tons capacities are identical with those having a single crank up to 9-in. shaft diameters; above that diameter the double-crank presses exceed the strength of single-crank presses rapidly as the shaft diameters increase. This increase is seen in the following reference table.

These tonnage figures do not apply to the end-wheel type of press, which has the overhanging crankpin. For tonnage capacities of these presses, square the diameter of the crankpin and multiply the result by 2½ tons. In this case the ultimate capacity is the shearing strength of the crankpin area.

Crankshafts are forged from commercial steel billets of about 0.45 per cent carbon content. For extra strength and continuous high speeds, chrome-nickel-molybdenum steel forgings are used.

Crankshaft diameter, inches	Single-crank press, tons	Double-crank press, tons
6½	150	150
7	180	180
7½	215	215
8	255	255
9	345	345
10	440	450
11	545	650
12	665	900
13	790	1,150
14	920	1,400
15	1,060	1,700
16	.....	2,000
16½	1,300	
17	.....	2,300
18	1,560	2,700
20	1,950	
22	2,380	
24	2,860	

Ultimate Shearing Strengths of Materials.—By using the following table of ultimate shearing strengths, it is possible to determine the pressure required for blanking a large variety of metals and nonmetallic materials. The table is based on using flat-faced cutting members, but for a shearing cut, when material does not exceed ¼ in. in thickness, use two-thirds of the tonnage given in the table; and for any thicknesses exceeding ¼ in., use three-fourths of the table tonnages. *Multiply the total cut length, or perimeter of the blank in inches, by the thickness of the material in inches, times the material tonnage given in the table.* The result is the tons pressure required for shearing or blanking with a flat-faced punch and die. If holes are pierced in the operation, their circumferences must also be added to the length of the blank outline.

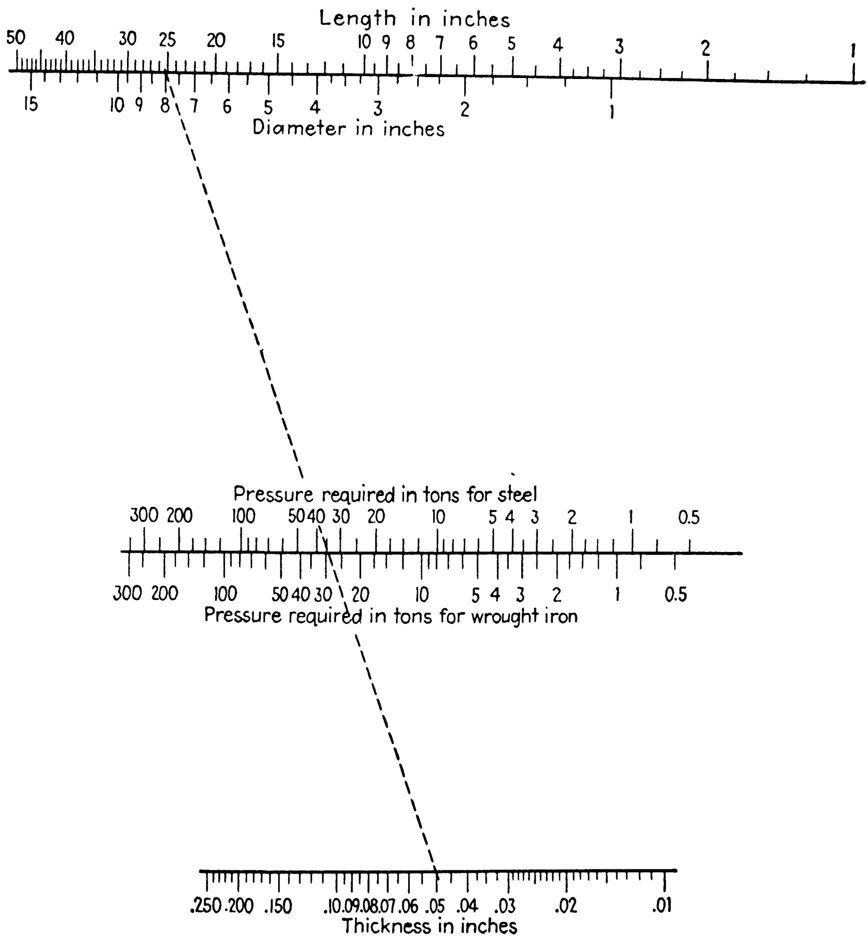
Ultimate Shearing Strength of Materials
Using Flat-faced Punch and Die

Material	Tons per sq. in.	Material	Tons per sq. in.
Aluminum, cast	6	Paper, using hollow die	1½
soft sheet	7½	using flat punch	4¼
half-hard sheet	9½	bristol, flat punch	2½
hard sheet	12½	strawboard, flat punch	1¾
Asbestos millboard	2	Silver	15
Brass, cast	18	Steel casting	30
soft sheet	15	boiler plate	30
half-hard sheet	17½	angle iron	30
hard sheet	20	cold-drawn rod	29
Bronze, gun metal	16	drill rod, not tempered	40
phosphor	20	nickel about 3¼ per cent	41
Copper, cast	12½	nickel about 5 per cent	42½
rolled	14	silicon	32½
Cupronickel	20	Stainless	35
Duralumin, soft sheet	15	0.10 carbon (soft)	22½
treated	17½	0.25 carbon (mild)	25
treated and cold rolled	20	0.50 carbon	35
Fiber, hard	12	0.75 carbon	40
Iron, cast	12½	1.00 carbon	42½
2 per cent nickel	25	1.20 carbon not tempered	47
wrought	20	1.20 carbon tempered	95
Lead	2	hot	⅙ to ¼ strength of cold
Leather, chrome	3½	Tin, cast	3
oak	3½	rolled sheet	2½
rawhide	6½	sheet steel coated with tin	25
Monel metal, cast	30	Zinc, sand cast	7
rolled sheet	32½	die cast	8
Nickel silver, half-hard sheet	16	rolled sheet	9
		hard rolled	10

For determining the press pressure required for forming or drawing operations, try out the operation in a hydraulic press that has a tonnage gage.

Example for Computing Blanking Pressure.—A blank with a total cut edge 12 in. long, and openings and round holes whose perimeters are 6 in. long, is to be perforated and blanked in a flat-faced punch and

PRESSURE CHART



To use the chart, first measure the number of inches in the cut, including the circumferences of the piercings, or, if the cut is circular, use the circumference of the blank. Mark this by a dot on the top line of the chart. Mark thickness of the metal on the lower line. If it is not known, find it with a micrometer.

Lay a ruler on the chart with the edge touching the dots on the upper and lower lines, and the reading of the scale on the center line will give the required pressure in tons for cutting the blank. (*Courtesy of Henry & Wright Mfg. Co.*)

die. This is a total of 18 in. for the length of all cut edges. The material is 0.10-carbon steel, No. 20 U. S. G. (0.036 in. thick). What is the combined perforating and blanking pressure required? *Solution:* $18 \times 0.036 \times 22\frac{1}{2} = 14.6$ tons. This job should be run in a press having a capacity around 25 tons.

TABLE SHOWING THE PENETRATION DEPTHS FOR MILD STEEL IN PUNCHING OPERATIONS

(Using a flat-faced punch)

Thickness, inches	1	3/4	5/8	1/2	3/8	5/16	1/4	3/16
Penetration per cent	0.25	0.31	0.34	0.37	0.44	0.47	0.50	0.56
Thickness, inches		1/8	3/32	1/16	1/32			
Penetration per cent		0.62	0.67	0.75	0.87			

Gage Sizes Used for Sheet Metals.—Strip steel is usually rolled to Birmingham wire gage sizes and sheets to U. S. Standard gage, although some mills roll both strip and sheet to the latter gage. Nonferrous metal sheets are rolled to Brown & Sharpe gage sizes, except zinc, which uses a sheet-zinc gage prepared by Matthiessen & Hegeler Zinc Company. Nonmetallic sheets are usually specified in decimal thicknesses of the common fractions of an inch. However, to avoid the confusion of the dozen or more gage sizes, it is advisable to specify all material thicknesses in decimal parts of an inch.

The U. S. Standard gage is primarily a weight and not a thickness gage. It was originally based on the weight of wrought iron at 0.2778 lb. per cubic inch, or 480 lb. per cubic foot. The numbers, or gage thicknesses, were to give a definite weight per square foot for each size. For example: No. 24 gage originally being 0.025 in. thick, wrought iron in this gage weighed 1.000 lb. per square foot. However, because the use of steel has practically superseded wrought iron for sheet use since the U. S. Standard gage was established, sheet-steel manufacturers revised the gage thicknesses for this table in 1938. Moreover, they based the new thicknesses on the average weight of steel at 0.2904 lb. per cubic inch.

Therefore, all the thicknesses in the following table, for the U. S. Standard gage, have been reduced to correspond with the weights per square foot of steel. It will be observed that these weights per square foot advance by $\frac{1}{32}$ lb., or multiples of $\frac{1}{32}$. This new table for U. S. gage sizes is now in practical use throughout the United States. Steels up to and including No. 5, or 0.2092 in. gage, are called "sheets"—above this size they are called "plates."

WEIGHTS OF SHEET STEEL, U.S. STANDARD REVISED, WASHBURN & MOEN, AND AMERICAN MUSIC WIRE GAGES

No. of gage	U. S. Standard revised gage	Weight per square foot, U. S. G.	Washburn & Moen steel wire gage	American Steel & Wire music wire gage	Decimal equivalents in fractions of an inch	
0000	0.40625	16.25	0.3938	0.006	1/64	0.016
000	0.375	15.00	0.3625	0.007	1/32	0.031
00	0.34375	13.75	0.331	0.008	3/64	0.047
0	0.3125	12.50	0.3065	0.009	1/16	0.062
1	0.28125	11.25	0.283	0.010	5/64	0.078
2	0.26562	10.625	0.2625	0.011	3/32	0.094
3	0.2391	10.00	0.2437	0.012	7/64	0.109
4	0.2242	9.375	0.2253	0.013	1/8	0.125
5	0.2092	8.75	0.207	0.014	9/64	0.140
6	0.1943	8.125	0.192	0.016	5/32	0.156
7	0.1793	7.50	0.177	0.018	11/64	0.172
8	0.1644	6.875	0.162	0.020	3/16	0.187
9	0.1495	6.25	0.1483	0.022	13/64	0.203
10	0.1345	5.625	0.135	0.024	7/32	0.219
11	0.1196	5.000	0.1205	0.026	15/64	0.234
12	0.1046	4.375	0.1055	0.029	1/4	0.250
13	0.0897	3.75	0.0915	0.031	9/32	0.281
14	0.0747	3.125	0.080	0.033	5/16	0.312
15	0.0673	2.813	0.072	0.035	11/32	0.344
16	0.0598	2.500	0.0625	0.037	3/8	0.375
17	0.0538	2.250	0.054	0.039	13/32	0.406
18	0.0478	2.000	0.0475	0.041	7/16	0.437
19	0.0418	1.750	0.041	0.043	15/32	0.469
20	0.0359	1.50	0.0348	0.045	1/2	0.500
21	0.0329	1.375	0.0317	0.047	17/32	0.531
22	0.0299	1.25	0.0286	0.049	9/16	0.562
23	0.0269	1.125	0.0258	0.051	19/32	0.594
24	0.0239	1.000	0.023	0.055	5/8	0.625
25	0.0209	0.875	0.0204	0.059	21/32	0.656
26	0.0179	0.750	0.0181	0.063	11/16	0.688
27	0.0164	0.6875	0.0173	0.067	23/32	0.718
28	0.0149	0.625	0.0162	0.071	3/4	0.750
29	0.0135	0.5625	0.015	0.075	25/32	0.781
30	0.0120	0.500	0.014	0.080	13/16	0.812
31	0.01094	0.4375	0.0132	0.085	27/32	0.844
32	0.01016	0.40625	0.0128	0.090	7/8	0.875
33	0.00938	0.375	0.0118	0.095	29/32	0.906
34	0.00859	0.34375	0.0104	0.100	15/16	0.937
35	0.00781	0.3125	0.0095	0.106	31/32	0.969
36	0.00703	0.28125	0.009	0.112	1	1.000

The governing factor in U. S. standard gages is the weights given per square foot.

Comparative Sizes of Different Gages for Wire and Sheet Metals in Decimal Parts of an Inch

Number of wire gage	American or Brown & Sharpe	Birmingham, or Stubs' iron wire	Washburn & Moen, steel wire gage	Washburn & Moen, steel music wire	New American S & W Co.'s music wire gage	Imperial wire gage	Stubs' steel wire drill rods	U. S. Standard gage* for sheet and plate iron and steel	Number of wire gage
00000000	....	.....	....	0.0083	.....	......	.....	....	00000000
0000000	....	.....	....	0.0087	.....	......	.....	....	0000000
000000	....	.....	....	0.0095	0.004	0.464	.....	0.46875	000000
00000	....	.....	....	0.010	0.005	0.432	.....	0.4375	00000
0000	0.460	0.454	0.3938	0.011	0.006	0.400	.....	0.40625	0000
000	0.40964	0.425	0.3625	0.012	0.007	0.372	.....	0.375	000
00	0.36485	0.380	0.3310	0.0133	0.008	0.348	.....	0.34375	00
0	0.32486	0.340	0.3065	0.0144	0.009	0.324	.....	0.3125	0
1	0.2893	0.300	0.2830	0.0156	0.010	0.300	0.227	0.28125	1
2	0.25763	0.284	0.2625	0.0166	0.011	0.276	0.219	0.265625	2
3	0.22942	0.259	0.2437	0.0178	0.012	0.252	0.212	0.250	3
4	0.20431	0.238	0.2253	0.0188	0.013	0.232	0.207	0.234375	4
5	0.18194	0.220	0.2070	0.0202	0.014	0.212	0.204	0.21875	5
6	0.16202	0.203	0.1920	0.0215	0.016	0.192	0.201	0.203125	6
7	0.14428	0.180	0.1770	0.023	0.018	0.176	0.199	0.1875	7
8	0.12849	0.165	0.1620	0.0243	0.020	0.160	0.197	0.171875	8
9	0.11443	0.148	0.1483	0.0256	0.022	0.144	0.194	0.15625	9
10	0.10189	0.134	0.1350	0.027	0.024	0.128	0.191	0.140625	10
11	0.090742	0.120	0.1205	0.0284	0.026	0.116	0.188	0.125	11
12	0.080808	0.109	0.1055	0.0296	0.029	0.104	0.185	0.109375	12
13	0.071961	0.095	0.0915	0.0314	0.031	0.092	0.182	0.09375	13
14	0.064084	0.083	0.0800	0.0326	0.033	0.080	0.180	0.078125	14
15	0.057068	0.072	0.0720	0.0345	0.035	0.072	0.178	0.0703125	15
16	0.05082	0.065	0.0625	0.036	0.037	0.064	0.175	0.0625	16
17	0.045257	0.058	0.0540	0.0377	0.039	0.056	0.172	0.05625	17
18	0.040303	0.049	0.0475	0.0395	0.041	0.048	0.168	0.050	18
19	0.03589	0.042	0.0410	0.0414	0.043	0.040	0.164	0.04375	19
20	0.031961	0.035	0.0348	0.0434	0.045	0.036	0.161	0.0375	20
21	0.028462	0.032	0.03175	0.046	0.047	0.032	0.157	0.034375	21
22	0.025347	0.028	0.0286	0.0483	0.049	0.028	0.155	0.03125	22
23	0.022571	0.025	0.0258	0.051	0.051	0.024	0.153	0.028125	23
24	0.0201	0.022	0.0230	0.055	0.055	0.022	0.151	0.025	24
25	0.0179	0.020	0.0204	0.0586	0.059	0.020	0.148	0.021875	25
26	0.01594	0.018	0.0181	0.0626	0.063	0.018	0.146	0.01875	26
27	0.014195	0.016	0.0173	0.0658	0.067	0.0164	0.143	0.0171875	27
28	0.012641	0.014	0.0162	0.072	0.071	0.0149	0.139	0.015625	28
29	0.011257	0.013	0.0150	0.076	0.075	0.0136	0.134	0.0140625	29
30	0.010025	0.012	0.0140	0.080	0.080	0.0124	0.127	0.0125	30
31	0.008928	0.010	0.0132	......	0.085	0.0116	0.120	0.0109375	31
32	0.00795	0.009	0.0128	......	0.090	0.0108	0.115	0.01015625	32
33	0.00708	0.008	0.0118	......	0.095	0.0100	0.112	0.009375	33
34	0.006304	0.007	0.0104	......	0.100	0.0092	0.110	0.00859375	34
35	0.005614	0.005	0.0095	......	0.106	0.0084	0.108	0.0078125	35
36	0.005	0.004	0.0090	......	0.112	0.0076	0.106	0.00703125	36
37	0.004453	.....	0.0085	......	.....	0.0068	0.103	0.006640625	37
38	0.003965	.....	0.0080	......	.....	0.0060	0.101	0.00625	38
39	0.003531	.....	0.0075	......	.....	0.0052	0.099	....	39
40	0.003144	.....	0.0070	......	.....	0.0048	0.097	....	40

* Original U. S. Standard gage sizes

Weights of Steel, Wrought Iron, Brass, and Copper Plates, Birmingham or Stub's Gage

No. of gage	Thickness, in.	Weight, lb. per sq. ft.			
		Steel	Iron	Brass	Copper
0000	0.454	18.52	18.16	19.431	20.556
000	0.425	17.34	17.00	18.190	19.253
00	0.380	15.30	15.20	16.264	17.214
0	0.340	13.87	13.60	14.552	15.402
1	0.300	12.24	12.00	12.840	13.590
2	0.284	11.59	11.36	12.155	12.865
3	0.259	10.57	10.36	11.085	11.733
4	0.238	9.71	9.52	10.186	10.781
5	0.220	8.98	8.80	9.416	9.966
6	0.203	8.28	8.12	8.689	9.196
7	0.180	7.34	7.20	7.704	8.154
8	0.165	6.73	6.60	7.062	7.475
9	0.148	6.04	5.92	6.334	6.704
10	0.134	5.47	5.36	5.735	6.070
11	0.120	4.90	4.80	5.137	5.436
12	0.109	4.45	4.36	4.667	4.938
13	0.095	3.88	3.80	4.066	4.303
14	0.083	3.39	3.32	3.552	3.769
15	0.072	2.94	2.88	3.081	3.262
16	0.065	2.65	2.60	2.782	2.945
17	0.058	2.37	2.32	2.482	2.627
18	0.049	2.00	1.96	2.097	2.220
19	0.042	1.71	1.68	1.797	1.902
20	0.035	1.43	1.40	1.498	1.585
21	0.032	1.31	1.28	1.369	1.450
22	0.028	1.14	1.12	1.198	1.270
23	0.025	1.02	1.00	1.070	1.132
24	0.022	0.898	0.88	0.941	0.997
25	0.020	0.816	0.80	0.856	0.906
26	0.018	0.734	0.72	0.770	0.815
27	0.016	0.653	0.64	0.685	0.725
28	0.014	0.571	0.56	0.599	0.634
29	0.013	0.530	0.52	0.556	0.589
30	0.012	0.490	0.48	0.514	0.544
31	0.010	0.408	0.40	0.428	0.453
32	0.009	0.367	0.36	0.385	0.408
33	0.008	0.326	0.32	0.342	0.362
34	0.007	0.286	0.28	0.2996	0.317
35	0.005	0.204	0.20	0.214	0.227
36	0.004	0.163	0.16	0.171	0.181

WEIGHTS OF ALUMINUM, BRASS, AND COPPER PLATES, AMERICAN OR BROWN & SHARPE GAGE

No. of gage	Thickness, in.	Weight, lb. per sq. ft.		
		Aluminum	Brass	Copper
0000	0.46	6.48	19.688	20.838
000	0.4096	5.77	17.533	18.557
00	0.3648	5.14	15.613	16.525
0	0.3249	4.58	13.904	14.716
1	0.2893	4.08	12.382	13.105
2	0.2576	3.63	11.027	11.670
3	0.2294	3.23	9.819	10.392
4	0.2043	2.88	8.745	9.255
5	0.1819	2.56	7.788	8.242
6	0.1620	2.28	6.935	7.340
7	0.1443	2.03	6.175	6.536
8	0.1285	1.81	5.499	5.821
9	0.1144	1.61	4.898	5.183
10	0.1019	1.44	4.631	4.616
11	0.0908	1.28	3.884	4.110
12	0.0808	1.14	3.458	3.660
13	0.0720	1.01	3.080	3.260
14	0.0641	0.903	2.743	2.903
15	0.0571	0.804	2.442	2.585
16	0.0508	0.716	2.175	2.302
17	0.0453	0.638	1.937	2.050
18	0.0403	0.568	1.725	1.825
19	0.0359	0.506	1.536	1.626
20	0.0320	0.450	1.367	1.448
21	0.0285	0.401	1.218	1.289
22	0.0253	0.357	1.085	1.148
23	0.0226	0.318	0.966	1.023
24	0.0201	0.283	0.860	0.910
25	0.0179	0.252	0.766	0.811
26	0.0159	0.225	0.682	0.722
27	0.0142	0.200	0.608	0.643
28	0.0126	0.178	0.541	0.573
29	0.0113	0.159	0.482	0.510
30	0.0100	0.141	0.429	0.454
31	0.0089	0.126	0.382	0.404
32	0.0080	0.113	0.340	0.360
33	0.0071	0.100	0.303	0.321
34	0.0063	0.0888	0.269	0.286
35	0.0056	0.0790	0.240	0.254
36	0.0050	0.0704	0.214	0.226
37	0.0045	0.0627	0.191	0.202
38	0.0040	0.0558	0.170	0.180
39	0.0035	0.0497	0.151	0.160
40	0.0031	0.0442	0.135	0.142

WEIGHT OF SHEET ZINC*

No. of gage	Thickness, in.	Lb. per sq. ft.	No. of gage	Thickness, in.	Lb. per sq. ft.	No. of gage	Thickness, in.	Lb. per sq. ft.
3	0.006	0.22	12	0.028	1.05	21	0.080	3.00
4	0.008	0.30	13	0.032	1.20	22	0.090	3.37
5	0.010	0.37	14	0.036	1.35	23	0.100	3.75
6	0.012	0.45	15	0.040	1.50	24	0.125	4.70
7	0.014	0.52	16	0.045	1.68	25	0.250	9.40
8	0.016	0.60	17	0.050	1.87	26	0.375	14.00
9	0.018	0.67	18	0.055	2.06	27	0.500	18.75
10	0.020	0.75	19	0.060	2.25	28	1.000	37.50
11	0.024	0.90	20	0.070	2.62			

* Matthiessen & Hegeler Zinc Co.

Weight per Square Foot for Any Sheet Material.—To find the weight per square foot of any sheet material not given in the tables, use the weight per cubic inch of the given material as found on pages 458 and 459. Multiply the weight per cubic inch by 0.144 times the number of thousandths of an inch in the given material thickness; this gives the weight in pounds per square foot. For example, 1 cu. in. of Stainless steel weighs 0.3033 lb.; then 1 sq. ft. of 0.083 gage weighs $0.3033 \times 0.144 \times 83$ or 3.625 lb.

Tin Plate

Tensile strength	50,000 lb. per square inch
Elastic limit	24,000 lb. per square inch
Elongation in 2 in.	35 per cent
Rockwell hardness	B-37
Erichsen value,*	7.5 mm. (0.295 in.)
Weight per cubic inch	0.2807 lb.

* Erichsen values are given for annealed samples 0.4 mm. ($\frac{1}{64}$ in.) in thickness.

The base for tin plate is thin sheets of either iron or steel. The base is coated with tin, and, in some instances, a composition of tin-lead alloys is used. The coating is evenly applied by methods similar to those used in the hot process of galvanizing sheet iron. If the coatings are smooth and free of small breaks or holes, the finished product is quite impervious to corrosion.

The standard sheet is 14 by 20 in. The smallest is 10 by 14 in., and the largest 26 by 26 in. The most economical size for ordinary use is probably 20 by 28 in. The number of sheets per box is usually 112 or 225, depending on size. Almost any desired size of plate, between the dimensions given above, is carried in stock. Boxes of tin weigh from

80 to 471 lb. The trade name for different thicknesses of tin plate is as follows:

Trade term	80 lb.	85 lb.	90 lb.	95 lb.	100 lb.	1C
Decimal thickness, in.	0.008	0.009	0.010	0.011	0.012	0.013
Weight per square foot	0.367	0.390	0.413	0.436	0.459	0.491

Trade term	1 × 1	IX	IXX	IXXX	IXXXX
Decimal thickness, in.	0.014	0.015	0.016	0.018	0.020
Weight per square foot	0.588	0.619	0.712	0.803	0.895

Pure tin is not used for drawing to a depth much beyond one-half the diameter, or the depth that can be drawn in a single operation. Obviously, it cannot be annealed in a furnace heat, and therefore an air furnace or oils of low boiling temperatures are used for normalizing.

There is, of course, a variation in the thickness of tin sheets, but they are manufactured within plus or minus 0.001 in. difference in thickness. The difference in some cases may be attributed to a little heavier coat of tin.

CUBIC-INCH WEIGHTS IN POUNDS OF VARIOUS MATERIALS*

	Pounds
Aluminum bronze, sheet	0.2783
Sheet	0.0980
Antimony	0.2422
Asbestos	0.1011
Asphaltum	0.0503
Bakelite	0.0446
Bauxite	0.0921
Bismuth	0.3538
Brass (sheet)	0.3080
Bronze	0.3195
Bronze phosphor (sheet)	0.3180
Cadmium	0.3105
Celluloid	0.0487
Chromium	0.2347
Concrete	0.0793
Copper (sheet)	0.3220
Cork	0.0087
Dow metal (magnesium)	0.0643
Duralumin	0.1010
Ebony wood (dry)	0.0450
Emery	0.1450
Fiber (vulcanized)	0.0510
German silver, or nickel silver	0.3160
Glass	0.0943

* Cubic-inch weight of any material equals 0.0361 lb. times the specific gravity of the material.

Cubic-inch Weights in Pounds of Various Materials.*—(*Continued*)

	Pounds
Gold, cast hammered	0.6975
U. S. coin	0.6209
Invar steel (36 per cent nickel)	0.3010
Iridium	0.8094
Iron, cast	0.2580
Sheet	0.2780
Ferrosilicon	0.2530
Wrought	0.2807
Kirksite "A"	0.2500
Lead	0.4110
Leather	0.0341
Maple wood (hard)	0.0250
Masonite	0.0480
Mercury	0.4910
Mica	0.1011
Micarta	0.0446
Molybdenum	0.3090
Monel metal, rolled	0.3212
Nickel	0.3140
Nickel silver	0.3160
Paper	0.0336
Pewter	0.2703
Platinum, sheet	0.7776
Wire	0.7595
Rubber, soft	0.0341
Hard, ebonite	0.0416
Saltpeter (potassium nitrate)	0.0761
Silver	0.3890
Slate	0.1012
Steel, crucible sheet	0.2853
Machinery	0.2818
Rolled sheet	0.2833
Stainless	0.3033
Tool	0 2853
2½ per cent silicon, transformer grade	0.2680
Sulphur	0.0724
Tin	0.2632
Tobin bronze	0.3040
Tungsten	0.6776
Vanadium	0.1986
Zinc, cast	0.2567
Rolled sheet	0.2600

* Cubic-inch weight of any material equals 0.0361 lb. times the specific gravity of the material.

DECIMAL FRACTIONS OF AN INCH

Fractions	Decimals	Fractions	Decimals
1/64	0.015625	33/64	0.515625
1/32	0.03125	17/32	0.53125
3/64	0.046875	35/64	0.546875
1/16	0.0625	9/16	0.5625
5/64	0.078125	37/64	0.578125
3/32	0.09375	19/32	0.59375
7/64	0.109375	39/64	0.609375
1/8	0.125	5/8	0.625
9/64	0.140625	41/64	0.640625
5/32	0.15625	21/32	0.65625
11/64	0.171875	43/64	0.671875
3/16	0.1875	11/16	0.6875
13/64	0.203125	45/64	0.703125
7/32	0.21875	23/32	0.71875
15/64	0.234375	47/64	0.734375
1/4	0.250	3/4	0.750
17/64	0.265625	49/64	0.765625
9/32	0.28125	25/32	0.78125
19/64	0.296875	51/64	0.796875
5/16	0.3125	13/16	0.8125
21/64	0.328125	53/64	0.828125
11/32	0.34375	27/32	0.84375
23/64	0.359375	55/64	0.859375
3/8	0.375	7/8	0.875
25/64	0.390625	57/64	0.890625
13/32	0.40625	29/32	0.90625
27/64	0.421875	59/64	0.921875
7/16	0.4375	15/16	0.9375
29/64	0.453125	61/64	0.953125
15/32	0.46875	31/32	0.96875
31/64	0.484375	63/64	0.984375
1/2	0.500	1	1.00000

Conversion Table, Millimeters into Decimal Inches

1 mm. = 0.03937 in.

Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches
1/100	0.00039	34/100	0.01339	67/100	0.02638	1	0.03937	34	1.33858
2/100	0.00079	35/100	0.01378	68/100	0.02677	2	0.07874	35	1.37795
3/100	0.00118	36/100	0.01417	69/100	0.02717	3	0.11811	36	1.41732
4/100	0.00157	37/100	0.01457	70/100	0.02756	4	0.15748	37	1.45669
5/100	0.00197	38/100	0.01496	71/100	0.02795	5	0.19685	38	1.49606
6/100	0.00236	39/100	0.01535	72/100	0.02835	6	0.23622	39	1.53543
7/100	0.00276	40/100	0.01575	73/100	0.02874	7	0.27559	40	1.57480
8/100	0.00315	41/100	0.01614	74/100	0.02913	8	0.31496	41	1.61417
9/100	0.00354	42/100	0.01654	75/100	0.02953	9	0.35433	42	1.65354
10/100	0.00394	43/100	0.01693	76/100	0.02992	10	0.39370	43	1.69291
11/100	0.00433	44/100	0.01732	77/100	0.03032	11	0.43307	44	1.73228
12/100	0.00472	45/100	0.01772	78/100	0.03071	12	0.47244	45	1.77165
13/100	0.00512	46/100	0.01811	79/100	0.03110	13	0.51181	46	1.81102
14/100	0.00551	47/100	0.01850	80/100	0.03150	14	0.55118	47	1.85039
15/100	0.00591	48/100	0.01890	81/100	0.03189	15	0.59055	48	1.88976
16/100	0.00630	49/100	0.01929	82/100	0.03228	16	0.62992	49	1.92913
17/100	0.00669	50/100	0.01969	83/100	0.03268	17	0.66929	50	1.96850
18/100	0.00709	51/100	0.02008	84/100	0.03307	18	0.70866	51	2.00787
19/100	0.00748	52/100	0.02047	85/100	0.03346	19	0.74803	52	2.04724
20/100	0.00787	53/100	0.02087	86/100	0.03386	20	0.78740	53	2.08661
21/100	0.00827	54/100	0.02126	87/100	0.03425	21	0.82677	54	2.12598
22/100	0.00866	55/100	0.02165	88/100	0.03465	22	0.86614	55	2.16535
23/100	0.00906	56/100	0.02205	89/100	0.03504	23	0.90551	56	2.20472
24/100	0.00945	57/100	0.02244	90/100	0.03543	24	0.94488	57	2.24409
25/100	0.00984	58/100	0.02283	91/100	0.03583	25	0.98425	58	2.28346
26/100	0.01024	59/100	0.02323	92/100	0.03622	26	1.02362	59	2.32283
27/100	0.01063	60/100	0.02362	93/100	0.03661	27	1.06299	60	2.36220
28/100	0.01102	61/100	0.02402	94/100	0.03701	28	1.10236	75	2.95275
29/100	0.01142	62/100	0.02441	95/100	0.03740	29	1.14173	88	3.46456
30/100	0.01181	63/100	0.02480	96/100	0.03780	30	1.18110	90	3.54330
31/100	0.01220	64/100	0.02520	97/100	0.03819	31	1.22047	105	4.13385
32/100	0.01260	65/100	0.02559	98/100	0.03858	32	1.25984		
33/100	0.01299	66/100	0.02598	99/100	0.03898	33	1.29921		

HARDNESS CONVERSION TABLE*

Rockwell hardness "C" Scale, 150-kg. load Brale penetrator	Rockwell hardness "A" Scale, 60-kg. load Brale penetrator	Sclero-scope	Mono-tron	Brinell hardness 10-mm. ball, 3,000-kg. load: Hardness number	Brinell hardness: Diameter in mm.	Approximate tensile strength of steel, lb. per sq. in.
20	59	36	29	226	4.02	110,000
25	62	40	34	253	3.80	123,000
30	65	45	39	288	3.60	140,000
32	66	47	41	304	3.50	147,000
34	67	49	43	321	3.40	156,000
36	68	51	45	337	3.32	164,000
38	69	53	47	356	3.24	173,000
40	70	55	49	376	3.15	184,000
42	71	57	51	396	3.07	195,000
44	72	59	54	417	3.00	208,000
46	74	61	57	439	2.92	220,000
48	75	64	60	461	2.85	233,000
50	76	66	63	486	2.77	252,000
52	77	69	66	517	2.70	268,000
54	78	72	70	546	2.62	285,000
56	79	75	74	560	2.57	304,000
58	80	78	78	595	2.52	324,000
60	81	81	82	614	2.48	342,000
61	82	82	84			
62	82	84	86			
63	83	86	89			
64	83	87	91			
65	84	89	94			
66	84	91	97			
67	85	94	101			
68	85	96	105			
69	86	98	109			
70	87	101	113			
70.5	88	102	115			

* Courtesy Illinois Tool Works.

Sheet-brass Tempers.—When brass sheets are passed through the mill rolls and reduced one Brown & Sharpe gage number, the material becomes ¼ harder. By this process, the following tempers are made:

Dead soft	Annealed
1	¼ hard
2	½ hard
3	¾ hard
4	Hard
6	Extra hard
8	Spring hard
10	Extra spring hard

Tolerances allowed are 0.00025 to 0.006 in. for Brown & Sharpe gage numbers from No. 38 to No. 0000, respectively.

Generally, ordinary brass is a copper-zinc alloy containing one-third zinc and two-thirds copper, but bronze is a copper and tin alloy containing about 10 per cent tin and 90 per cent copper. Gun metal contains 90 to 92 per cent copper and 8 to 10 per cent tin. Lead is frequently added in these mixtures to improve machining conditions, and both tin and zinc are used in the same alloys, so that we have a series of copper-tin-zinc alloys of multitudinous variety. All these useful alloys, however, contain more than 50 per cent of copper. The weight of brass sheet is 0.308 lb. per cubic inch.

Copper alloys that are best known under a trade name are as follows:

Trade name	Copper	Zinc	Manganese	Tin
Gilding metal	95	5		
Tombac brass	91	9		
Tombac red brass	88	12		
Fourney's alloy	82.5	17.5		
Red brass	82	18		
Dutch metal	80	18	2	
Delotot's alloy	80	20		
Imitation gold leaf	78	22		
Cartridge brass	70	30		
Two-and-one brass	66	34		
Naval brass	62	37	..	1
Muntz metal	60	40		
Brazing solders	50	50		

All these brasses belong in the alpha class and are therefore ductile.

Aluminum.—Numerous aluminum alloys are available in the form of sheet. The most commonly used designations for these materials are as follows:

Alloy	Per cent of alloying elements; aluminum and normal impurities constitute remainder*								
	Copper	Silicon	Manganese	Magnesium	Zinc	Nickel	Chromium	Lead	Bismuth
2S									
3S	....	...	1.2						
4S	....	...	1.2	1.0					
17S	4.0	...	0.5	0.5					
A17S	2.5	...	...	0.3					
24S	4.6	...	0.6	1.5					
51S	....	1.0	...	0.6					
52S	..	...	...	2.5	. .	...	0.25		
53S	....	0.7	...	1.3	. .	. .	0.25		
61S	0.25	0.6	. .	1.0	..	...	0.25		

* This table and the one following are used by permission of the Aluminum Company of America.

The symbols used to designate the tempers of these alloys are:

O = soft annealed.
$\frac{1}{4}$H = $\frac{1}{4}$ hard.
$\frac{1}{2}$H = $\frac{1}{2}$ hard.
$\frac{3}{4}$H = $\frac{3}{4}$ hard.
H = hard.
W = quenched (solution treatment only).
T = quenched and aged (solution treatment followed by precipitation).
RT = cold worked after heat-treatment.

Of the alloys listed, 17S, A17S, and 24S are heat-treatable alloys at ordinary room temperature and are, therefore, available in the T, or heat-treated-and-aged, condition as well as in the annealed condition. Alloys 53S and 61S are also heat-treatable, but they are different from the first three in that complete aging does not occur at room temperature after quenching. This is a distinct advantage when difficult forming operations are to be imposed, because the forming can be carried out on material in the W, or quenched condition, and then the formed article can be aged to the T condition to develop higher strength.

TYPICAL MECHANICAL PROPERTIES OF WROUGHT-ALUMINUM ALLOYS

Alloy and temper	Tension				Hardness	Shear	Fatigue
	Yield strength (set = 0.2 %), lb. per sq. in.	Ultimate strength, lb. per sq. in.	Elongation, per cent in 2 in.		Brinell 500 kg. 10-mm. ball	Shearing strength, lb. per sq. in.	Endurance limit, lb. per sq. in.
			Sheet specimen (1/16 in. thick)	Round specimen (1/2 in. diameter)			
2S-O	5,000	13,000	35	45	23	9,500	5,000
2S-¼H	13,000	15,000	12	25	28	10,000	6,000
2S-½H	14,000	17,000	9	20	32	11,000	7,000
2S-¾H	17,000	20,000	6	17	38	12,000	8,500
2S-H	21,000	24,000	5	15	44	13,000	8,500
3S-O	6,000	16,000	30	40	28	11,000	7,000
3S-¼H	15,000	18,000	10	20	35	12,000	8,000
3S-½H	18,000	21,000	8	16	40	14,000	9,000
3S-¾H	21,000	25,000	5	14	47	15,000	9,500
3S-H	25,000	29,000	4	10	55	16,000	10,000
4S-O	10,000	26,000	20	25	45	16,000	14,000
4S-¼H	22,000	31,000	10	17	52	17,000	14,500
4S-½H	27,000	34,000	9	12	63	18,000	15,000
4S-¾H	31,000	37,000	5	9	70	20,000	15,500
4S-H	34,000	40,000	5	6	77	21,000	16,000
17S-O	10,000	26,000	20	22	45	18,000	11,000
17S-T	37,000	60,000	20	22	100	36,000	15,000
17S-RT	47,000	65,000	13	..	110	38,000	
Alclad 17S-T	33,000	56,000	18	..	...	32,000	
Alclad 17S-RT	40,000	57,000	11	..	...	32,000	
A17S-O	8,000	22,000	24	27	38	15,000	
A17S-T	24,000	43,000	24	27	70	26,000	13,500
24S-O	10,000	26,000	20	22	42	18,000	12,000
24S-T	44,000	68,000	19	22	105	41,000	18,000
24S-RT	55,000	70,000	13	..	116	42,000	
Alclad 24S-T	41,000	62,000	18	..	...	40,000	
Alclad 24S-RT	50,000	66,000	11	..	...	41,000	
51S-O	6,000	16,000	30	35	28	11,000	6,500
51S-W	20,000	35,000	24	30	64	24,000	10,500
51S-T	40,000	48,000	14	16	95	30,000	10,500
52S-O	14,000	29,000	25	30	45	18,000	17,000
52S-¼H	26,000	34,000	12	18	62	20,000	18,000
52S-½H	29,000	37,000	10	14	67	21,000	19,000
52S-¾H	34,000	39,000	8	10	74	23,000	20,000
52S-H	36,000	41,000	7	8	85	24,000	20,500
53S-O	7,000	16,000	25	35	26	11,000	7,500
53S-W	20,000	33,000	22	30	65	20,000	10,000
53S-T	33,000	39,000	14	20	80	24,000	11,000
61S-O	8,000	18,000	22	..	30	12,500	7,500
61S-W	21,000	35,000	22	..	65	24,000	12,500
61S-T	39,000	45,000	12	..	95	30,000	12,500
61S-T8	47,000	52,000	10	..	98	32,000	

LENGTHS OF ARCS FOR 90-DEG. BENDS ACROSS THE GRAIN IN V DIES

Formula $(T/3 + R) \times 1.5708$

Radius R	T = thickness of metal, in.															
	0.010	0.015	0.020	0.025	0.031	0.037	0.050	0.062	0.078	0.093	0.109	0.125	0.140	0.156	0.187	0.250
0	0.0052	0.0079	0.0105	0.0131	0.0162	0.0193	0.0262	0.0325	0.0408	0.0487	0.0570	0.0655	0.0734	0.0817	0.0979	0.1308
0.005	0.0130	0.0157	0.0184	0.0209	0.0240	0.0272	0.0340	0.0404	0.0487	0.0565	0.0649	0.0733	0.0812	0.0895	0.1057	0.1387
0.010	0.0209	0.0236	0.0262	0.0287	0.0319	0.0350	0.0419	0.0482	0.0565	0.0644	0.0727	0.0812	0.0891	0.0974	0.1136	0.1466
0.015	0.0287	0.0314	0.0341	0.0366	0.0397	0.0429	0.0498	0.0561	0.0644	0.0723	0.0806	0.0891	0.0970	0.1052	0.1214	0.1544
0.020	0.0366	0.0393	0.0419	0.0445	0.0476	0.0507	0.0576	0.0639	0.0723	0.0801	0.0884	0.0969	0.1048	0.1131	0.1293	0.1623
1/32	0.0542	0.0569	0.0595	0.0620	0.0652	0.0683	0.0752	0.0815	0.0898	0.0977	0.1060	0.1145	0.1224	0.1307	0.1469	0.1799
1/16	0.1034	0.1060	0.1087	0.1112	0.1144	0.1175	0.1244	0.1307	0.1390	0.1469	0.1552	0.1637	0.1715	0.1799	0.1960	0.2290
3/32	0.1524	0.1550	0.1577	0.1602	0.1634	0.1665	0.1734	0.1797	0.1880	0.1959	0.2042	0.2126	0.2205	0.2289	0.2450	0.2780
1/8	0.2015	0.2042	0.2069	0.2094	0.2125	0.2157	0.2226	0.2289	0.2372	0.2450	0.2534	0.2618	0.2697	0.2780	0.2942	0.3272
5/32	0.2505	0.2532	0.2559	0.2584	0.2615	0.2647	0.2716	0.2779	0.2862	0.2940	0.3024	0.3109	0.3187	0.3270	0.3432	0.3762
3/16	0.2997	0.3024	0.3050	0.3076	0.3107	0.3138	0.3208	0.3270	0.3354	0.3432	0.3515	0.3600	0.3679	0.3762	0.3924	0.4254
7/32	0.3487	0.3514	0.3540	0.3566	0.3597	0.3629	0.3698	0.3760	0.3844	0.3922	0.4006	0.4090	0.4169	0.4252	0.4414	0.4744
1/4	0.3979	0.4006	0.4032	0.4057	0.4089	0.4120	0.4189	0.4252	0.4335	0.4414	0.4497	0.4582	0.4661	0.4744	0.4906	0.5235
9/32	0.4469	0.4496	0.4522	0.4547	0.4579	0.4610	0.4679	0.4742	0.4825	0.4904	0.4987	0.5072	0.5151	0.5234	0.5396	0.5726
5/16	0.4961	0.4987	0.5014	0.5039	0.5071	0.5102	0.5171	0.5234	0.5317	0.5396	0.5479	0.5564	0.5642	0.5726	0.5887	0.6217
3/8	0.5942	0.5969	0.5996	0.6021	0.6052	0.6084	0.6153	0.6216	0.6299	0.6377	0.6461	0.6546	0.6624	0.6707	0.6869	0.7199
1/2	0.7906	0.7933	0.7959	0.7984	0.8016	0.8047	0.8116	0.8179	0.8262	0.8341	0.8424	0.8507	0.8588	0.8671	0.8833	0.9162

LENGTHS OF ARCS FOR 90-DEG. BENDS ACROSS THE GRAIN IN SPRING-PAD BENDING DIES
[Formula $(T/5 + R) \times 1.5708$]

Radius R	T = thickness of metal, in.															
	0.010	0.015	0.020	0.025	0.031	0.037	0.050	0.062	0.078	0.093	0.109	0.125	0.140	0.156	0.187	0.250
0	0.0031	0.0047	0.0063	0.0079	0.0097	0.0116	0.0157	0.0195	0.0245	0.0292	0.0342	0.0393	0.0440	0.0490	0.0587	0.0785
0.005	0.0110	0.0126	0.0141	0.0157	0.0176	0.0195	0.0236	0.0273	0.0324	0.0371	0.0421	0.0471	0.0518	0.0569	0.0666	0.0864
0.010	0.0188	0.0204	0.0220	0.0236	0.0254	0.0273	0.0314	0.0352	0.0402	0.0449	0.0500	0.0550	0.0597	0.0647	0.0745	0.0942
0.015	0.0267	0.0283	0.0298	0.0314	0.0333	0.0352	0.0393	0.0430	0.0480	0.0528	0.0578	0.0628	0.0675	0.0726	0.0823	0.1021
0.020	0.0346	0.0361	0.0377	0.0393	0.0412	0.0430	0.0471	0.0509	0.0559	0.0606	0.0656	0.0707	0.0754	0.0804	0.0901	0.1100
1/32	0.0522	0.0537	0.0553	0.0569	0.0587	0.0606	0.0647	0.0685	0.0735	0.0782	0.0833	0.0883	0.0930	0.0980	0.1078	0.1275
1/16	0.1013	0.1029	0.1045	0.1060	0.1079	0.1098	0.1139	0.1177	0.1227	0.1274	0.1324	0.1374	0.1422	0.1472	0.1570	0.1767
3/32	0.1503	0.1519	0.1535	0.1550	0.1570	0.1588	0.1629	0.1667	0.1717	0.1764	0.1814	0.1865	0.1912	0.1962	0.2059	0.2257
1/8	0.1995	0.2011	0.2026	0.2042	0.2061	0.2080	0.2121	0.2158	0.2209	0.2256	0.2306	0.2356	0.2403	0.2454	0.2551	0.2749
5/32	0.2485	0.2501	0.2516	0.2532	0.2551	0.2570	0.2611	0.2648	0.2699	0.2746	0.2796	0.2846	0.2893	0.2944	0.3041	0.3239
3/16	0.2977	0.2992	0.3008	0.3024	0.3043	0.3061	0.3102	0.3140	0.3190	0.3237	0.3288	0.3338	0.3385	0.3435	0.3533	0.3731
7/32	0.3467	0.3482	0.3498	0.3514	0.3533	0.3551	0.3592	0.3630	0.3680	0.3727	0.3778	0.3828	0.3875	0.3925	0.4023	0.4221
1/4	0.3958	0.3973	0.3990	0.4006	0.4024	0.4043	0.4084	0.4122	0.4172	0.4219	0.4269	0.4320	0.4367	0.4417	0.4514	0.4712
9/32	0.4448	0.4464	0.4480	0.4496	0.4514	0.4533	0.4574	0.4612	0.4662	0.4709	0.4760	0.4810	0.4857	0.4907	0.5005	0.5202
5/16	0.4940	0.4956	0.4972	0.4987	0.5006	0.5025	0.5066	0.5104	0.5154	0.5201	0.5251	0.5301	0.5349	0.5399	0.5496	0.5694
3/8	0.5922	0.5938	0.5953	0.5969	0.5988	0.6007	0.6048	0.6085	0.6136	0.6183	0.6233	0.6283	0.6330	0.6381	0.6478	0.6676
1/2	0.7885	0,7901	0,7917	0.7933	0.7951	0.7970	0.8011	0.8049	0.8099	0.8146	0.8196	0.8247	0.8294	0.8344	0.8441	0.8639

Tables for Lengths of Right-angle Bends.—In bending mild-tempered sheet metals in V-block dies, Fig. 355, the neutral bending line N is theoretically located at one-third of the material thickness from inside the bends when the bends are made across the grain. For Fig. 355, the table on page 466 gives the lengths of arc X when bending 90-deg. angles in the commonly used gage thicknesses. The table on p. 467

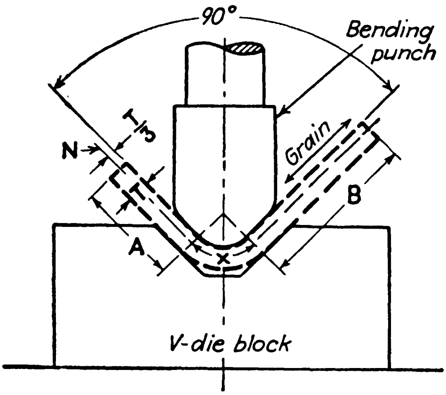


Fig. 355.—A typical V-block bending die.

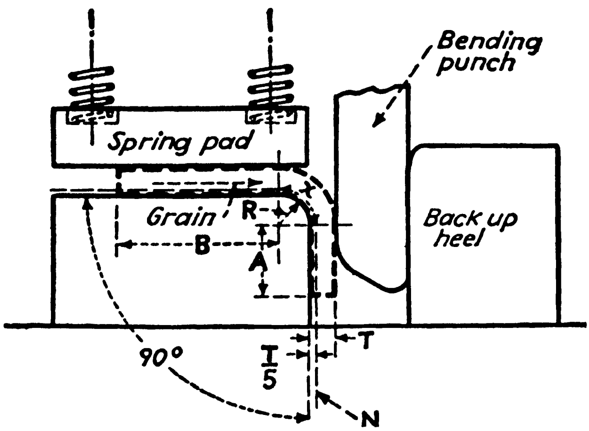


Fig. 356.—A typical spring-pad bending die.

gives the lengths of arc X when bending mild tempered sheet metals in spring-pad bending dies as shown in Fig. 356. Here, the bending line N is theoretically located at one-fifth of the material thickness from inside of bends made across the grain. In both Figs. 355 and 356, the developed length of the piece is $A + X + B$. For the arc lengths of other angles than 90 deg., length X is proportional to the number of degrees in the bend. For example, in a 1-deg. bend, length X is one-ninetieth of the tabulated dimensions given in the tables.

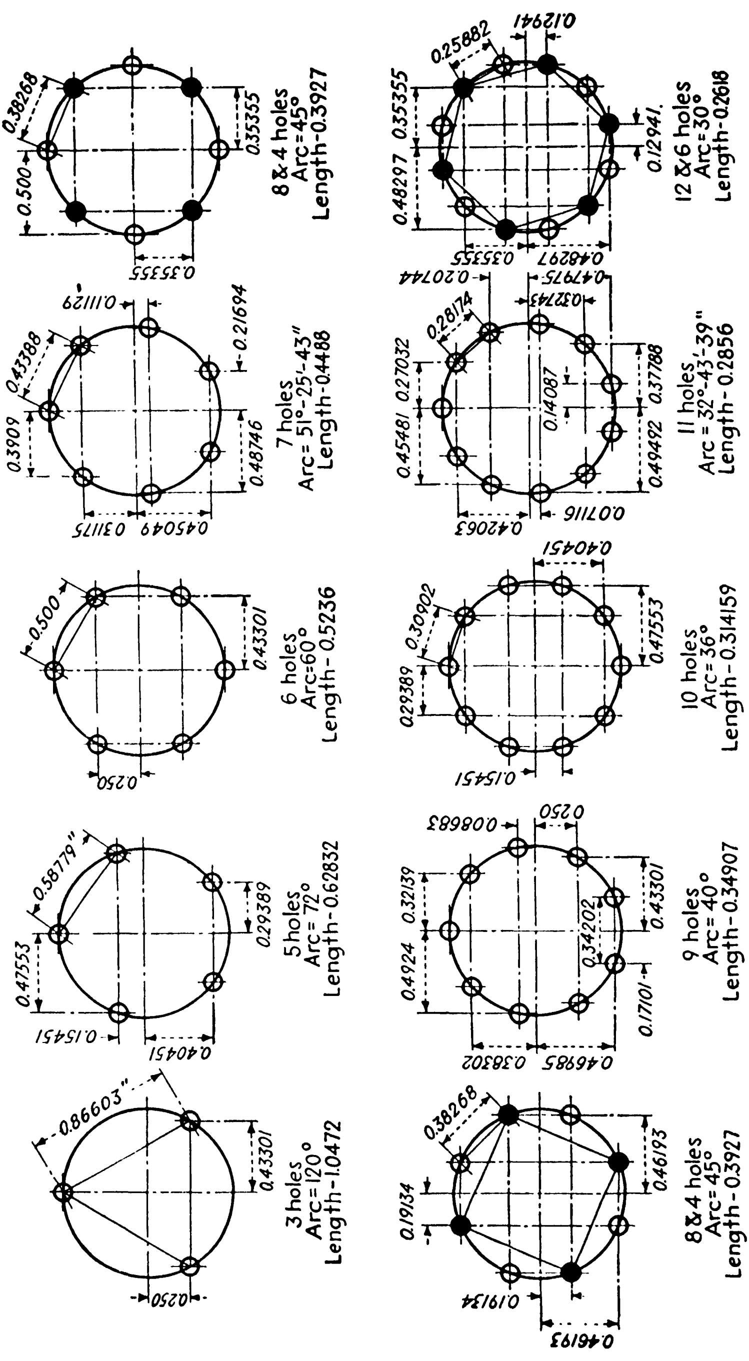


Fig. 357.—Dimensions between equally spaced centers on circles 1 in. in diameter.

Changing Circular Dimensions to Vertical and Horizontal.—This change is often desirable when jig boring holes in dies, jigs, fixtures, and other work. So-called "straight dimensions" are easier to make a setup for jig boring than setting up the circular attachment on the machine. It is also easier for the designer in giving his dimensions.

In Fig. 357 are 13 cases in which all the necessary dimensions between equally spaced centers are worked out for circles 1 in. in diameter. To find the straight dimensions, chords, or length of arcs in any given circle, multiply the values shown in Fig. 357 by the diameter of the given circle.

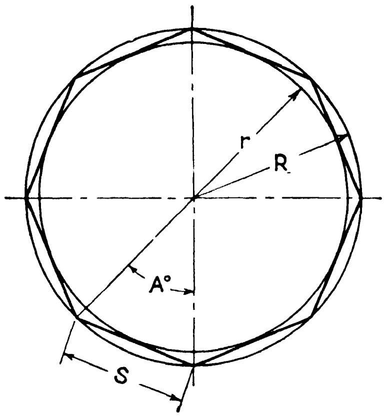


FIG. 358.

ANGLE A, AREA, RADIUS OF INSCRIBED AND CIRCUMSCRIBED CIRCLES FOR REGULAR POLYGONS*

Name of figure	Number of sides	$A°$	Area	Radius r of inscribed circle	Radius R of circumscribed circle
Triangle, equal sides	3	120°	$0.43301 \times S^2$	$0.28867 \times S$	$0.57735 \times S$
Square	4	90°	$1.00000 \times S^2$	$0.50000 \times S$	$0.70711 \times S$
Pentagon	5	72°	$1.72048 \times S^2$	$0.68819 \times S$	$0.85065 \times S$
Hexagon	6	60°	$2.59808 \times S^2$	$0.86603 \times S$	$1.00000 \times S$
Heptagon	7	51° 25′ 43″	$3.63391 \times S^2$	$1.03830 \times S$	$1.15230 \times S$
Octagon	8	45°	$4.82843 \times S^2$	$1.20710 \times S$	$1.30650 \times S$
Nonagon	9	40°	$6.18182 \times S^2$	$1.37370 \times S$	$1.46190 \times S$
Decagon	10	36°	$7.69421 \times S^2$	$1.53880 \times S$	$1.61800 \times S$
Undecagon	11	32° 43′ 39″	$9.36564 \times S^2$	$1.70280 \times S$	$1.77470 \times S$
Dodecagon	12	30°	$11.19615 \times S^2$	$1.86603 \times S$	$1.93180 \times S$

* This table refers to Fig. 358. For all other dimensions, use the constants given for a circle 1 in. in diameter, shown in Fig. 357, and from which this table was computed.

Natural Trigonometric Functions.—In any triangle, when one of its angles is a right angle, or 90 deg. (Fig. 359), and when the length of its hypotenuse c is unity, or 1, by dividing the length of any one side by the length of another side we get a quotient that is a natural trigonometric function of the acute angles A and B. By this method, all the given decimal figures for the sines, cosines, tangents, and other trigonometric functions of angles have been computed and classified in handbook tables. The following formulas cover the solutions for practically all the triangular problems that arise in tool engineering practice.

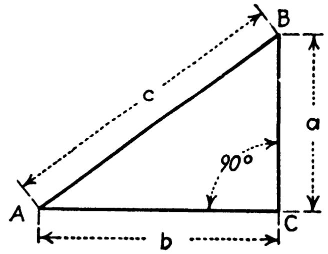


Fig. 359.—Illustrating the derivation of the natural trigonometric functions for a right-angled triangle.

$$\sin A = \frac{a}{c} \qquad a = \sin A \times c \qquad c = \frac{a}{\sin A}$$

$$\cos A = \frac{b}{c} \qquad b = \cos A \times c \qquad c = \frac{b}{\cos A}$$

$$\tan A = \frac{a}{b} \qquad a = \tan A \times b \qquad b = \frac{a}{\tan A}$$

$$\cot A = \frac{b}{a} \qquad b = \cot A \times a \qquad a = \frac{b}{\cot A}$$

$$\sec A = \frac{c}{b} \qquad c = \sec A \times b \qquad b = \frac{c}{\sec A}$$

$$\csc A = \frac{c}{a} \qquad c = \csc A \times a \qquad a = \frac{c}{\csc A}$$

Solving Oblique Triangles.—When the three sides A, B, and C are known (Fig. 360) and the unknown dimensions are to be solved,

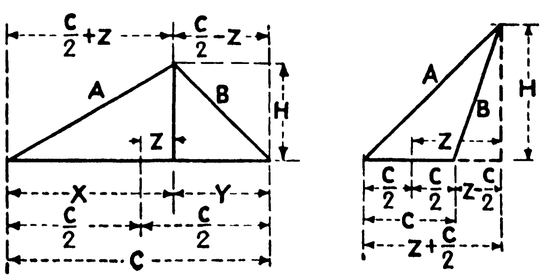


Fig. 360.—Illustrating the formulas for solving X, Y, Z, H and all the angles, given the three sides A, B, and C.

lay out and letter the triangle as shown and proceed to determine dimension Z. The formula used is $Z = (A^2 - B^2)/2C$. It is appar-

ent that, when Z is solved, all the remaining unknown dimensions can be found. The need for this formula often arises in locating centers for boring holes in dies, for bushing holes in drilling jigs, and for general tool engineering.

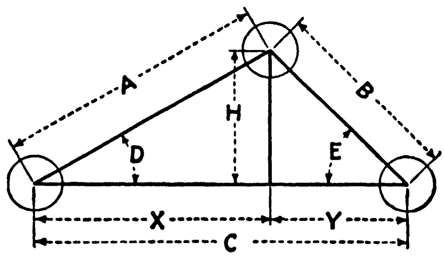


FIG. 361.—Illustrating the formulas for solving the vertical height H and the horizontal dimensions X and Y, given A, B, and C.

Solving the Vertical and Horizontal Dimensions for Triangles.—In Fig. 361, dimensions A, B, and C are given, and H, X, and Y are required.

$$X = \frac{A^2 + C^2 - B^2}{2C}, \qquad Y = C - X, \qquad \text{and} \qquad H = \sqrt{A^2 - X^2}.$$

Another solution for H is to find angles D and E, as given by formulas in the preceding figure; then

$$H = \frac{C}{\cot D + \cot E}$$

Formulas for Circular Segments.—Referring to Fig. 362, we can derive the following formulas:

$$\frac{H}{B} = \frac{B}{X} \qquad B^2 = HX$$

$$X = \frac{B^2}{H} \qquad H = R(\text{versin } A)$$

$$\text{versin } A = \frac{H}{R} \qquad R = \frac{H + X}{2}$$

$$R = \frac{H}{\text{versin } A} \qquad R = \frac{B^2 + H^2}{2H}$$

$$B = \sqrt{2HR - H^2} \qquad B = \sin A \times R$$

$$\sin A = \frac{B}{R} \qquad H = R - \sqrt{R^2 - B^2}$$

$$E = R - H \qquad E = \cos A \times R$$

$$E = \sqrt{R^2 - B^2}$$

Length of arc $L = 0.0174533 \times R \times L$ deg., in which the number of degrees in L is used as a whole number or a whole number and decimal fraction. The versed sine of angle A is omitted in the tables of many handbooks, but it is a useful function and is found by subtracting cos A from unity: versin $A = 1.0000 - \cos A$.

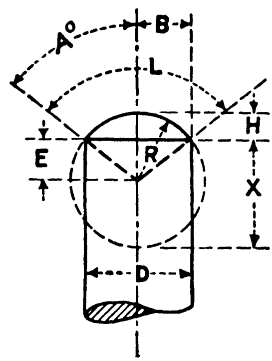


FIG. 362.—Illustrating the formulas used for determining the heights of arcs and the inaccessible centers of arcs and circles and for spherical segments.

Computing Pulley and Gear Speeds.—It should always be kept in mind which wheel is the driver and which is to be driven. As illustrated in Fig. 363, the diameter of the driver times its r.p.m. equals the diameter of the driven times its r.p.m. What is the required pulley diameter on a motor shaft that revolves 1,800 r.p.m. that will cause a press flywheel, which is 30 in. in diameter, to revolve 120 r.p.m. when belted up? Using the foregoing formula, the required diameter D is

$$D \times 1{,}800 = 30 \times 120. \quad D = \frac{30 \times 120}{1{,}800}, \text{ or 2 in.}$$

Gear ratios are similarly figured, pitch diameters being used instead of pulley diameters. If the pitch diameters are unknown, count the

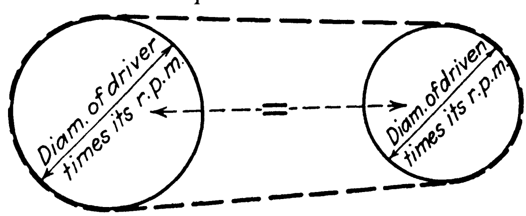


FIG. 363.—Showing the equality relationship between the speeds of driver and driven pulleys.

number of teeth in the gears; then the number of teeth in the driving gear times its r.p.m. equals the number of teeth in the driven times its r.p.m.

Calculating Press-ram Descents.—In Fig. 364 all dimensions are in inches, and

A = angle of crank movement from zero.
B = angle of driving arm movement from zero.
T = "throw" or crank radius.
L = effective length of driving arm.
x = arc height of crank radius.
y = arc height of driving-arm radius.

Then

$$x - y = \text{ram descent}$$
$$x = T(\text{versin } A)$$
$$y = L(\text{versin } B)$$
$$\sin B = \frac{\sin A \times T}{L}$$
$$\text{versin } A = 1.0000 - \cos A$$
$$\text{versin } B = 1.0000 - \cos B$$

In Fig. 365 all dimensions are in inches, and

$$x = \sin (A - 90°)T + T$$
$$\sin B = \frac{\cos (A - 90°)T}{L}$$

The remaining formulas for Fig. 365 are the same as those given under Fig. 364; that is, $y = L(\text{versin } B)$, and $x - y =$ ram descent.

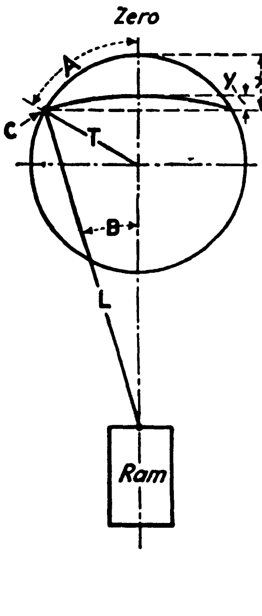


Fig. 364.—Illustrating the formula for calculating ram descent when crank C has advanced less than 90 deg.

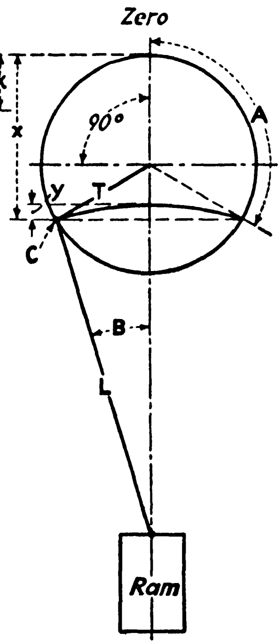


Fig. 365.—Illustrating the formula for calculating ram descent when crank C has passed 90 deg.

When calculating the ram positions at points in its ascent, as at 248 deg. crank movement from zero, use the difference between 360

and 248 deg., or 112 deg., for A. This computation should always be made when the crank movement from zero is greater than 180 deg.

The following formula will give the ram descent directly, even though the crank has passed 90 deg.

$$\text{Ram descent} = T + \frac{[\sin (A - B)]T}{\sin B} - L.$$

These formulas are useful for determining the position of the slide or piston head in crank-driven motors, relative to any assumed arc travel of the crank. They can be applied for solving the movements in any arm and pitman driving mechanism.

Position of Crankpin at One-half the Ram Descent.—If $x - y =$ the ram descent, then a press ram (or punch) has descended one-half its full stroke when the height y of its driving-arm radius is tangent to the center line D-D, or passes through the crankshaft center at F, Fig. 366.

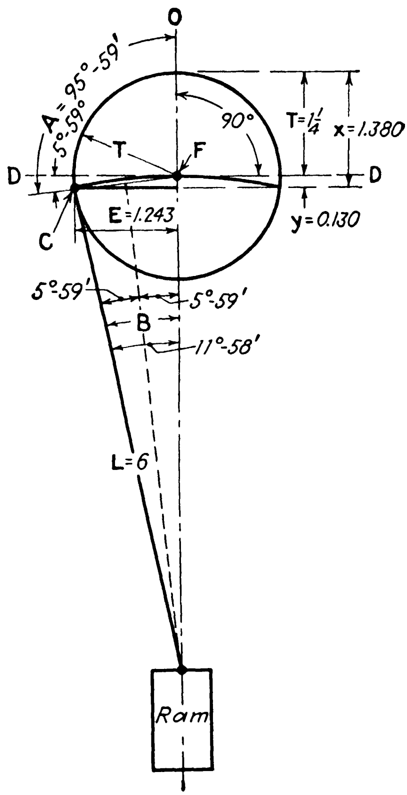


FIG. 366.—Solving the position for crankpin C at one-half the ram descent.

In Fig. 366 consider $T = 1\frac{1}{4}$ in., $L = 6$ in., and that the driving-arm radius passes through F. By dividing the driving-arm angle B into two right triangles, as shown, and solving one of them, we find that angle $B = 11$ deg. 58 min. and that the angle of crank advance $A = 95$ deg. 59 min. Solving for x and y, $x = 1.380$ in., $y = 0.130$ in., and $x - y = 1\frac{1}{4}$ in., which is the ram descent and also one-half its full stroke.

It is usually near this point of high ram velocity that the punch contacts the blank when drawing fairly deep shells. Some manufacturers use coated metal, as coated blanks will take the thrust of the drawing punch more easily. The sheets are purchased tinned, copper plated, or lead coated.

Velocity Travel of Press Rams.—Referring again to Fig. 366 and assuming that the crankshaft is running 60 r.p.m. and solving E, which is one-half the chord of the driving-arm radius, we find that $E = 1.243$ in. The velocity travel V, in feet per minute, of the ram (or punch), at any position of crankpin C, is $V = 0.524 \times E \times$ r.p.m. In the case under consideration, $V = 0.524 \times 1.243 \times 60 = 39.08$ ft. per minute; 0.524 is a constant.

Tap-hole Diameters.—Actual tests have shown that an ordinary steel nut that is tapped with only half of a full thread and greatly overtightened on a bolt will "strip" the bolt threads first. A 75 per cent depth of thread is therefore of ample strength in common tapping practice and is easy economical tapping. A full depth of thread, while difficult to obtain, is actually only 5 per cent stronger than a 75 per cent thread, and it requires three times more power to cut. A full thread should be used in metals only when the material thickness is half the tap diameter or less. Full threads may be used economically in most nonmetallic materials or compositions.

The formula for determining a tap-hole diameter T, for U. S. Form threads,* when D is the outside diameter of the tap and N the number of threads per lineal inch, is: $T = D$ minus $(0.9743/N)$. The single depth S for a U. S. Form thread is: $S = 0.65000/N$, and the percentage of thread is: $= N(D$ minus $T)/1.3$. Tap-hole diameters for U. S. Form threads may be quickly obtained by using the following easily remembered formula. When D is the maximum diameter of the tap, and E the linear distance from thread to thread, or $1.000/N$, then: $T = D$ minus E. This formula gives approximately a 75 per cent thread.

Tap-hole sizes depend largely upon the ductility of the material being tapped, and the same rule applies to threading dies. Soft metals "flow" and close slightly while being threaded, and hard metals do not. A general rule is to use a full thread in thicknesses *less* than half the tap diameter, and a 75 per cent thread for depths up to *twice* the tap diameter, and a 50 per cent thread for deeper holes. The following tables for tap-hole diameters are used by diemakers in tool construction. They may also be used for manufacturing operations.

* A.S.M.E. and S.A.E. threads are U. S. Form.

TAP DRILL SIZES FOR 75 PER CENT DEPTH OF THREAD
MACHINE SCREW THREADS

Tap size	Threads per in.	Diam. of tap hole	Use drill	Tap size	Threads per in.	Diam. of tap hole	Use drill
0	80*	0.048	3/64	10	32	0.160	21
1	72*	0.060	53	10	30*	0.158	22
1	64	0.058	53	10	24	0.149	25
2	64*	0.071	50	12	28*	0.181	14
2	56	0.069	50	12	24	0.175	16
3	56*	0.082	45	14	24*	0 201	7
3	48	0.079	47	14	20	0.193	10
4	48*	0.092	42	16	22*	0.224	2
4	40	0.088	43	16	20	0.219	7/32
4	36	0.085	44	16	18	0.214	3
5	44*	0.103	37	18	20*	0.245	D
5	40	0.101	38	18	18	0.240	B
5	36	0.098	40	20	20*	0.271	I
6	40*	0.114	33	20	18	0.266	17/64
6	36	0.111	34	22	18*	0.292	L
6	32	0.108	36	22	16	0.285	9/32
7	36*	0.124	1/8	24	18	0.318	O
7	32	0.121	31	24	16*	0.311	5/16
7	30	0.119	31	26	16*	0.337	R
8	36*	0.137	29	26	14	0.328	21/64
8	32	0.134	29	28	16	0.363	23/64
8	30	0.132	30	28	14*	0.354	T
9	32*	0.147	26	30	16	0.389	25/64
9	30	0.145	27	30	14*	0.380	V
9	24	0.136	29				

* A.S.M.E. standard.

Tap Drill Sizes for 75 Per Cent Depth of Thread
U. S. and S.A.E. Standards

Tap size	Threads per in.	Diam. tap hole	Use drill	Tap size	Threads per in.	Diam. tap hole	Use drill	Tap size	Threads per in.	Diam. tap hole	Use drill
1/16	72	0.049	3/64	1/4	32	0.220	7/32	7/8	14*	0.805	13/16
1/16†	64	0.047	3/64	1/4	28*	0.215	3	7/8	12	0.794	51/64
1/16	60	0.046	56	1/4	27	0.214	3	7/8†	9	0.767	49/64
5/64	72	0.065	52	1/4	24	0.209	4	15/16	12	0.856	55/64
5/64	64	0.063	1/16	1/4†	20	0.201	7	15/16†	9	0.829	53/64
5/64†	60	0.062	1/16	5/16	32	0.282	9/32	1	27	0.964	31/32
5/64	56	0.061	53	5/16	27	0.276	J	1	14*	0.930	15/16
3/32	60	0.077	5/64	5/16	24*	0.272	I	1	12	0.919	59/64
3/32	56	0.076	48	5/16	20	0.264	17/64	1†	8	0.878	7/8
3/32†	50	0.074	49	5/16†	18	0.258	F	1 1/16	8	0.941	15/16
3/32	48	0.073	49	3/8	27	0.339	R	1 1/8	12*	1.044	1 3/64
7/64	56	0.092	42	3/8	24*	0.334	Q	1 1/8†	7	0.986	63/64
7/64	50	0.090	43	3/8	20	0.326	21/64	1 3/16	7	1.048	1 3/64
7/64†	48	0.089	43	3/8†	16	0.314	5/16	1 1/4	12*	1.169	1 11/64
1/8	48	0.105	36	7/16	27	0.401	Y	1 1/4†	7	1 111	1 7/64
1/8†	40	0.101	38	7/16	24	0.397	X	1 5/16	7	1.173	1 11/64
1/8	36	0.098	40	7/16	20*	0.389	25/64	1 3/8	12*	1.294	1 19/64
1/8	32	0.095	3/32	7/16†	14	0.368	U	1 3/8†	6	1.213	1 7/32
9/64†	40	0.116	32	1/2	27	0.464	15/32	1 1/2	12*	1.419	1 27/64
9/64	36	0.114	33	1/2	24	0.460	29/64	1 1/2†	6	1.338	1 11/32
9/64	32	0.110	35	1/2	20*	0.451	29/64	1 5/8†	5 1/2	1.448	1 29/64
5/32	40	0.132	30	1/2†	13	0.425	27/64	1 3/4†	5	1.555	1 9/16
5/32†	36	0.129	30	1/2	12	0.419	27/64	1 7/8†	5	1.680	1 11/16
5/32	32	0.126	1/8	9/16	27	0.526	17/32	2†	4 1/2	1.783	1 25/32
11/64	36	0.145	27	9/16	18*	0.508	33/64	2 1/8†	4 1/2	1.909	1 29/32
11/64†	32	0.141	9/64	9/16†	12	0.481	31/64	2 1/4†	4 1/2	2.034	2 1/32
3/16	36	0.161	20	5/8	27	0.589	19/32	2 3/8†	4	2.131	2 1/8
3/16	32	0.157	22	5/8	18*	0.571	37/64	2 1/2†	4	2.256	2 1/4
3/16	30	0.155	23	5/8	12	0.544	35/64	2 5/8†	4	2.381	2 3/8
3/16†	24	0.147	26	5/8†	11	0.536	17/32	2 3/4†	4	2.506	2 1/2
13/64	32	0.173	17	11/16	16*	0.627	5/8	2 7/8†	3 1/2	2.597	2 19/32
13/64	30	0.171	11/64	11/16†	11	0.599	19/32	3†	3 1/2	2.722	2 23/32
13/64†	24	0.163	20	3/4	27	0.714	23/32	3 1/8†	3 1/2	2.847	2 27/32
7/32	32	0.188	12	3/4	16*	0.689	11/16	3 1/4†	3 1/2	2.972	2 31/32
7/32	28	0.184	13	3/4	12	0.669	43/64	3 3/8†	3 1/4	3.075	3 1/16
7/32†	24	0.178	16	3/4†	10	0.653	21/32	3 1/2†	3 1/4	3.200	3 3/16
15/64	32	0.204	6	13/16	12	0.731	47/64	3 5/8†	3 1/4	3.325	3 5/16
15/64	28	0.200	8	13/16†	10	0.715	23/32	3 3/4†	3	3.425	3 7/16
15/64†	24	0.194	10	7/8	27	0.839	27/32	3 7/8†	3	3.550	3 9/16
				7/8	18*	0.821	53/64	4†	3	3.675	3 11/16

* S.A.E. Standard.
† U. S. Standard.

DIAMETERS OF NUMBERED TWIST DRILLS COMPARED WITH STUB'S DRILL ROD DIAMETERS

No.	Drill	Rod	No.	Drill	Rod	No.	Drill	Rod	No.	Drill	Rod
1	0.2280	0.227	28	0.1405	0.139	55	0.0520	0.050	A	0.234	0.234
2	0.2210	0.219	29	0.1360	0.134	56	0.0465	0.045	B	0.238	0.238
3	0.2130	0.212	30	0.1285	0.127	57	0.0430	0.042	C	0.242	0.242
4	0.2090	0.207	31	0.1200	0.120	58	0.0420	0.041	D	0.246	0.246
5	0.2055	0.204	32	0.1160	0.115	59	0.0410	0.040	E	0.250	0.250
6	0.2040	0.201	33	0.1130	0.112	60	0.0400	0.039	F	0.257	0.257
7	0.2010	0.199	34	0.1110	0.110	61	0.0390	0 038	G	0.261	0.261
8	0.1990	0.197	35	0.1100	0.108	62	0.0380	0.037	H	0.266	0.266
9	0.1960	0.194	36	0.1065	0.106	63	0.0370	0.036	I	0.272	0.272
10	0.1935	0.191	37	0.1040	0.103	64	0.0360	0.035	J	0.277	0.277
11	0.1910	0.188	38	0.1015	0.101	65	0.0350	0.033	K	0.281	0.281
12	0.1890	0.185	39	0.0995	0.099	66	0.0330	0.032	L	0.290	0.290
13	0.1850	0.182	40	0.0980	0.097	67	0.0320	0.031	M	0.295	0.295
14	0.1820	0.180	41	0.0960	0.095	68	0.0310	0.030	N	0.302	0.302
15	0.1800	0.178	42	0.0935	0.092	69	0.0292	0.029	O	0.316	0.316
16	0.1770	0.175	43	0.0890	0.088	70	0.0280	0.027	P	0.323	0.323
17	0.1730	0.172	44	0.0860	0.085	71	0.0260	0.026	Q	0.332	0.332
18	0.1695	0.168	45	0.0820	0.081	72	0.0250	0.024	R	0.339	0.339
19	0.1660	0.164	46	0.0810	0.079	73	0.0240	0.023	S	0.348	0.348
20	0.1610	0.161	47	0.0785	0.077	74	0.0225	0.022	T	0.358	0.358
21	0.1590	0.157	48	0.0760	0.075	75	0.0210	0.020	U	0.368	0.368
22	0.1570	0.155	49	0.0730	0.072	76	0.0200	0.018	V	0.377	0.377
23	0.1540	0.153	50	0.0700	0.069	77	0.0180	0.016	W	0.386	0.386
24	0.1520	0.151	51	0.0670	0.066	78	0.0160	0.015	X	0.397	0.397
25	0.1495	0.148	52	0.0635	0.063	79	0.0145	0.014	Y	0.404	0.404
26	0.1470	0.146	53	0.0595	0.058	80	0.0135	0.013	Z	0.413	0.413
27	0.1440	0.143	54	0.0550	0.055						

All dimensions are given in decimal fractions of an inch.

Approximate Blank Diameters for Cylindrical Shells

Diameter of shell, in.	Height of shell, in.																				
	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4
1/4	0.75	0.83	0.90	0.97	1.03	1.09	1.15	1.20	1.25	1.30	1.34	1.39	1.43	1.52	1.59	1.67	1.75	1.82	1.89	1.95	2.02
3/8	0.94	1.04	1.13	1.21	1.28	1.34	1.42	1.48	1.55	1.61	1.67	1.71	1.78	1.88	1.98	2.07	2.16	2.24	2.32	2.40	2.48
1/2	1.12	1.22	1.32	1.41	1.50	1.58	1.66	1.73	1.80	1.87	1.93	2.00	2.07	2.18	2.29	2.39	2.50	2.60	2.69	2.78	2.88
5/8	1.28	1.40	1.50	1.60	1.70	1.79	1.88	1.96	2.04	2.11	2.19	2.26	2.32	2.46	2.58	2.69	2.80	2.92	3.02	3.12	3.23
3/4	1.44	1.56	1.67	1.78	1.89	1.98	2.08	2.16	2.25	2.33	2.41	2.48	2.56	2.70	2.84	2.96	3.09	3.21	3.32	3.43	3.54
7/8	1.59	1.72	1.84	1.95	2.06	2.16	2.26	2.36	2.45	2.54	2.62	2.70	2.78	2.94	3.08	3.22	3.38	3.50	3.63	3.75	3.84
1	1.73	1.87	2.00	2.12	2.23	2.34	2.45	2.55	2.64	2.74	2.82	2.91	3.00	3.16	3.31	3.46	3.61	3.74	3.87	4.00	4.13
1 1/8	1.87	2.02	2.15	2.28	2.40	2.51	2.62	2.73	2.83	2.93	3.02	3.11	3.21	3.37	3.53	3.69	3.84	3.98	4.12	4.26	4.39
1 1/4	2.01	2.16	2.30	2.43	2.56	2.68	2.80	2.90	3.01	3.11	3.22	3.31	3.40	3.58	3.75	3.91	4.07	4.22	4.37	4.51	4.65
1 3/8	2.16	2.31	2.45	2.59	2.72	2.84	2.96	3.08	3.18	3.29	3.39	3.49	3.59	3.77	3.95	4.12	4.28	4.44	4.59	4.74	4.88
1 1/2	2.29	2.45	2.60	2.74	2.87	3.00	3.12	3.24	3.36	3.46	3.58	3.67	3.77	3.97	4.15	4.33	4.50	4.66	4.82	4.97	5.12
1 5/8	2.42	2.59	2.74	2.89	3.02	3.15	3.28	3.40	3.52	3.63	3.74	3.85	3.95	4.15	4.34	4.53	4.70	4.87	5.03	5.20	5.35
1 3/4	2.56	2.72	2.88	3.03	3.17	3.30	3.43	3.56	3.68	3.80	3.91	4.03	4.14	4.34	4.54	4.73	4.90	5.08	5.25	5.42	5.57
1 7/8	2.70	2.86	3.02	3.18	3.32	3.46	3.59	3.72	3.84	3.97	4.08	4.20	4.30	4.52	4.71	4.91	5.10	5.28	5.45	5.62	5.79
2	2.83	3.00	3.16	3.31	3.46	3.61	3.75	3.87	4.00	4.12	4.24	4.36	4.47	4.69	4.90	5.10	5.29	5.48	5.65	5.83	6.00
2 1/8	2.96	3.13	3.30	3.46	3.61	3.75	3.89	4.02	4.16	4.28	4.40	4.52	4.64	4.86	5.08	5.28	5.48	5.67	5.85	6.03	6.21
2 1/4	3.09	3.27	3.44	3.60	3.75	3.90	4.04	4.18	4.31	4.44	4.56	4.68	4.80	5.03	5.25	5.46	5.66	5.86	6.05	6.23	6.41
2 3/8	3.22	3.40	3.57	3.74	3.89	4.04	4.18	4.32	4.46	4.59	4.72	4.84	4.96	5.20	5.42	5.64	5.84	6.04	6.24	6.42	6.61
2 1/2	3.35	3.54	3.71	3.87	4.03	4.18	4.33	4.47	4.61	4.74	4.87	5.00	5.12	5.36	5.59	5.81	6.02	6.22	6.42	6.61	6.80
2 5/8	3.48	3.67	3.84	4.01	4.17	4.32	4.47	4.62	4.76	4.89	5.03	5.15	5.28	5.52	5.76	5.98	6.20	6.40	6.61	6.80	6.99
2 3/4	3.61	3.80	3.98	4.15	4.31	4.47	4.62	4.76	4.90	5.04	5.18	5.31	5.44	5.68	5.92	6.15	6.37	6.58	6.79	6.99	7.18
2 7/8	3.75	3.93	4.11	4.28	4.45	4.60	4.76	4.91	5.05	5.19	5.33	5.46	5.59	5.84	6.08	6.32	6.54	6.76	6.96	7.17	7.37
3	3.87	4.06	4.24	4.42	4.58	4.74	4.90	5.05	5.20	5.34	5.48	5.61	5.74	6.00	6.25	6.48	6.71	6.93	7.14	7.35	7.55
3 1/8	4.00	4.19	4.38	4.55	4.72	4.88	5.04	5.19	5.34	5.48	5.63	5.76	5.90	6.16	6.40	6.64	6.87	7.10	7.32	7.52	7.73
3 1/4	4.13	4.32	4.51	4.68	4.85	5.02	5.18	5.33	5.48	5.63	5.77	5.91	6.05	6.31	6.56	6.80	7.04	7.26	7.48	7.70	7.91
3 3/8	4.26	4.45	4.64	4.82	4.99	5.15	5.31	5.47	5.62	5.77	5.92	6.05	6.19	6.47	6.72	6.96	7.20	7.43	7.66	7.87	8.08
3 1/2	4.39	4.58	4.77	4.95	5.12	5.29	5.45	5.61	5.77	5.91	6.06	6.20	6.35	6.61	6.87	7.12	7.37	7.60	7.83	8.05	8.26
3 5/8	4.51	4.71	4.90	5.08	5.26	5.43	5.59	5.75	5.90	6.06	6.21	6.35	6.49	6.76	7.03	7.28	7.52	7.76	7.99	8.21	8.43
3 3/4	4.64	4.84	5.03	5.21	5.39	5.56	5.73	5.89	6.04	6.20	6.35	6.49	6.63	6.91	7.18	7.43	7.68	7.92	8.16	8.38	8.60
3 7/8	4.77	4.97	5.16	5.34	5.52	5.69	5.86	6.02	6.18	6.34	6.49	6.64	6.78	7.06	7.33	7.59	7.84	8.08	8.32	8.55	8.77
4	4.90	5.10	5.29	5.48	5.66	5.83	6.00	6.16	6.32	6.48	6.63	6.78	6.92	7.21	7.48	7.74	8.00	8.24	8.48	8.71	8.94
4 1/8	5.02	5.22	5.42	5.61	5.79	5.96	6.13	6.30	6.46	6.62	6.77	6.92	7.07	7.36	7.63	7.89	8.15	8.40	8.64	8.88	9.11
4 1/4	5.15	5.35	5.55	5.74	5.92	6.09	6.27	6.43	6.60	6.76	6.91	7.06	7.21	7.50	7.78	8.05	8.31	8.56	8.80	9.04	9.27
4 3/8	5.28	5.48	5.68	5.87	6.05	6.23	6.40	6.57	6.73	6.89	7.05	7.21	7.35	7.64	7.93	8.20	8.46	8.71	8.96	9.20	9.44
4 1/2	5.40	5.61	5.81	6.00	6.18	6.36	6.53	6.70	6.87	7.03	7.19	7.35	7.50	7.79	8.07	8.35	8.61	8.87	9.12	9.36	9.60

APPROXIMATE BLANK DIAMETERS FOR CYLINDRICAL SHELLS.—(*Continued*)

Diameter of shell, in.	Height of shell, in.																				
	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4
4 5/8	5.53	5.74	5.93	6.13	6.31	6.49	6.67	6.84	7.01	7.17	7.33	7.48	7.64	7.93	8.22	8.50	8.76	9.02	9.28	9.52	9.76
4 3/4	5.66	5.86	6.06	6.26	6.44	6.62	6.80	6.97	7.14	7.31	7.47	7.62	7.78	8.08	8.37	8.64	8.91	9.18	9.43	9.68	9.92
4 7/8	5.78	5.99	6.19	6.39	6.57	6.76	6.93	7.11	7.28	7.44	7.60	7.76	7.92	8.22	8.51	8.79	9.06	9.33	9.59	9.84	10.08
5	5.91	6.12	6.32	6.52	6.70	6.89	7.07	7.24	7.41	7.58	7.74	7.90	8.06	8.36	8.66	8.94	9.21	9.48	9.74	10.00	10.24
5 1/8	6.04	6.25	6.45	6.64	6.83	7.02	7.20	7.37	7.55	7.72	7.88	8.04	8.21	8.51	8.80	9.09	9.37	9.63	9.90	10.15	10.40
5 1/4	6.17	6.37	6.58	6.77	6.96	7.15	7.33	7.51	7.68	7.85	8.02	8.18	8.34	8.65	8.94	9.23	9.51	9.78	10.05	10.31	10.56
5 3/8	6.29	6.50	6.71	6.90	7.09	7.28	7.46	7.64	7.82	7.99	8.15	8.31	8.48	8.79	9.09	9.38	9.66	9.93	10.20	10.46	10.72
5 1/2	6.42	6.63	6.83	7.03	7.22	7.41	7.60	7.77	7.95	8.12	8.29	8.45	8.61	8.93	9.23	9.52	9.81	10.08	10.35	10.62	10.87
5 5/8	6.54	6.76	6.96	7.16	7.35	7.54	7.73	7.91	8.08	8.25	8.42	8.59	8.75	9.07	9.37	9.67	9.95	10.23	10.50	10.77	11.02
5 3/4	6.67	6.88	7.09	7.29	7.48	7.67	7.86	8.04	8.22	8.39	8.56	8.72	8.89	9.20	9.51	9.81	10.10	10.38	10.65	10.92	11.18
5 7/8	6.80	7.01	7.22	7.42	7.61	7.80	7.99	8.17	8.35	8.52	8.69	8.86	9.02	9.34	9.65	9.95	10.24	10.52	10.80	11.07	11.33
6	6.92	7.14	7.34	7.55	7.74	7.93	8.12	8.30	8.48	8.66	8.83	9.00	9.16	9.48	9.79	10.09	10.39	10.67	10.95	11.22	11.48
6 1/4	7.18	7.39	7.60	7.80	8.00	8.19	8.38	8.57	8.75	8.92	9.10	9.27	9.44	9.76	10.07	10.38	10.68	10.96	11.25	11.52	11.79
6 1/2	7.43	7.64	7.85	8.06	8.26	8.45	8.64	8.83	9.01	9.19	9.36	9.54	9.71	10.03	10.35	10.66	10.96	11.25	11.54	11.82	12.09
6 3/4	7.68	7.90	8.11	8.31	8.51	8.71	8.90	9.09	9.27	9.45	9.63	9.80	9.97	10.31	10.63	10.94	11.25	11.54	11.83	12.11	12.39
7	7.93	8.15	8.36	8.57	8.77	8.97	9.16	9.35	9.53	9.72	9.90	10.07	10.24	10.58	10.90	11.22	11.53	11.83	12.12	12.40	12.68
7 1/4	8.18	8.40	8.62	8.82	9.03	9.22	9.42	9.61	9.80	9.98	10.16	10.34	10.51	10.85	11.18	11.50	11.81	12.11	12.41	12.70	12.98
7 1/2	8.44	8.66	8.87	9.08	9.28	9.48	9.68	9.87	10.06	10.24	10.42	10.60	10.78	11.12	11.45	11.77	12.09	12.39	12.69	12.99	13.27
7 3/4	8.69	8.91	9.12	9.33	9.54	9.74	9.94	10.13	10.32	10.50	10.69	10.87	11.04	11.39	11.72	12.05	12.37	12.68	12.98	13.27	13.56
8	8.94	9.16	9.38	9.59	9.79	10.00	10.19	10.39	10.58	10.77	10.95	11.13	11.31	11.66	11.99	12.32	12.64	12.96	13.26	13.56	13.85
8 1/4	9.19	9.41	9.63	9.84	10.05	10.25	10.45	10.65	10.84	11.03	11.21	11.39	11.57	11.92	12.27	12.60	12.92	13.23	13.54	13.84	14.14
8 1/2	9.44	9.66	9.88	10.10	10.30	10.51	10.71	10.90	11.10	11.29	11.47	11.66	11.84	12.19	12.53	12.87	13.20	13.51	13.82	14.13	14.43
8 3/4	9.69	9.92	10.13	10.35	10.56	10.76	10.96	11.16	11.36	11.55	11.73	11.92	12.10	12.46	12.80	13.14	13.47	13.79	14.10	14.41	14.71
9	9.95	10.17	10.39	10.60	10.81	11.02	11.21	11.42	11.61	11.81	11.99	12.18	12.36	12.72	13.07	13.41	13.74	14.07	14.38	14.69	14.99
9 1/4	10.20	10.42	10.64	10.85	11.07	11.27	11.48	11.68	11.87	12.07	12.26	12.44	12.63	12.99	13.34	13.68	14.02	14.34	14.66	14.97	15.28
9 1/2	10.45	10.67	10.89	11.11	11.32	11.53	11.73	11.93	12.13	12.32	12.52	12.70	12.89	13.25	13.61	13.95	14.29	14.61	14.9[illegible]	15.25	15.56
9 3/4	10.70	10.92	11.14	11.36	11.57	11.78	11.99	12.19	12.39	12.58	12.77	12.96	13.15	13.52	13.87	14.22	14.56	14.89	15.21	15.53	15.84
10	10.95	11.18	11.40	11.61	11.83	12.04	12.24	12.44	12.64	12.84	13.03	13.22	13.41	13.78	14.14	14.49	14.83	15.16	15.49	15.81	16.12
10 1/4	11.20	11.43	11.65	11.87	12.08	12.29	12.50	12.70	12.90	13.10	13.29	13.48	13.67	14.04	14.40	14.75	15.10	15.43	15.76	16.08	16.40
10 1/2	11.45	11.68	11.90	12.12	12.33	12.54	12.75	12.96	13.16	13.36	13.55	13.74	13.93	14.30	14.66	15.02	15.36	15.70	16.03	16.36	16.68
10 3/4	11.70	11.93	12.15	12.37	12.59	12.80	13.01	13.21	13.41	13.61	13.81	14.00	14.19	14.56	14.93	15.29	15.63	15.97	16.31	16.63	16.95
11	11.95	12.18	12.40	12.62	12.84	13.05	13.26	13.47	13.67	13.87	14.07	14.26	14.45	14.83	15.19	15.55	15.90	16.24	16.58	16.91	17.22
11 1/4	12.20	12.43	12.67	12.91	13.09	13.30	13.52	13.72	13.93	14.13	14.33	14.52	14.71	15.08	15.46	15.82	16.17	16.52	16.84	17.17	17.50
11 1/2	12.45	12.65	12.90	13.11	13.35	13.56	13.77	13.98	14.18	14.38	14.58	14.78	14.97	15.35	15.72	16.08	16.43	16.78	17.11	17.45	17.78
11 3/4	12.66	12.92	13.16	13.39	13.59	13.82	14.03	14.23	14.44	14.63	14.84	15.04	15.22	15.60	15.98	16.34	16.70	17.05	17.39	17.73	18.05
12	12.96	13.20	13.42	13.63	13.86	14.07	14.28	14.49	14.70	14.88	15.10	15.30	15.50	15.88	16.24	16.61	16.96	17.32	17.66	18.00	18.33

APPROXIMATE BLANK DIAMETERS FOR CYLINDRICAL SHELLS.—(*Continued*)

Diameter of shell, in.	Height of shell, in.																			
	4¼	4½	4¾	5	5¼	5½	5¾	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12
¼	2.08	2.13	2.20	2.25	2.31	2.36	2.41	2.46	2.56	2.66	2.75	2.83	2.93	3.01	3.09	3.17	3.25	3.33	3.40	3.48
⅜	2.55	2.63	2.70	2.76	2.83	2.90	2.96	3.03	3.15	3.27	3.38	3.48	3.59	3.70	3.80	3.90	3.98	4.08	4.17	4.26
½	2.96	3.04	3.12	3.20	3.28	3.35	3.42	3.50	3.64	3.77	3.90	4.03	4.15	4.27	4.39	4.50	4.61	4.71	4.82	4.93
⅝	3.32	3.42	3.50	3.59	3.68	3.76	3.84	3.92	4.08	4.23	4.38	4.52	4.65	4.78	4.91	5.04	5.16	5.28	5.39	5.51
¾	3.65	3.75	3.85	3.94	4.03	4.13	4.22	4.30	4.48	4.64	4.80	4.96	5.10	5.25	5.39	5.53	5.66	5.79	5.92	6.05
⅞	3.95	4.06	4.17	4.27	4.39	4.47	4.57	4.66	4.84	5.03	5.19	5.36	5.52	5.68	5.83	5.98	6.12	6.26	6.40	6.53
1	4.24	4.35	4.46	4.58	4.69	4.79	4.89	5.00	5.19	5.39	5.57	5.74	5.92	6.08	6.24	6.40	6.56	6.71	6.86	7.00
1⅛	4.51	4.63	4.75	4.87	4.98	5.10	5.21	5.31	5.52	5.72	5.92	6.10	6.28	6.46	6.63	6.80	6.96	7.12	7.28	7.43
1¼	4.78	4.90	5.03	5.15	5.27	5.39	5.50	5.61	5.84	6.04	6.25	6.45	6.64	6.82	7.00	7.18	7.35	7.52	7.68	7.84
1⅜	5.02	5.16	5.29	5.42	5.54	5.67	5.79	5.90	6.13	6.35	6.57	6.78	6.97	7.16	7.35	7.54	7.73	7.89	8.07	8.24
1½	5.26	5.40	5.54	5.68	5.81	5.93	6.07	6.19	6.42	6.65	6.87	7.09	7.30	7.50	7.70	7.89	8.08	8.26	8.44	8.62
1⅝	5.50	5.64	5.78	5.92	6.06	6.20	6.33	6.45	6.70	6.94	7.17	7.39	7.61	7.82	8.02	8.22	8.42	8.61	8.80	8.98
1¾	5.72	5.88	6.02	6.17	6.31	6.45	6.58	6.71	6.97	7.22	7.46	7.69	7.91	8.13	8.34	8.55	8.75	8.95	9.14	9.33
1⅞	5.95	6.10	6.25	6.41	6.55	6.69	6.83	6.96	7.23	7.49	7.73	7.97	8.20	8.43	8.64	8.86	9.07	9.27	9.48	9.67
2	6.16	6.32	6.48	6.63	6.78	6.93	7.07	7.21	7.49	7.75	8.00	8.25	8.48	8.72	8.94	9.17	9.38	9.59	9.80	10.00
2⅛	6.38	6.54	6.70	6.86	7.01	7.16	7.31	7.45	7.73	8.00	8.26	8.52	8.76	9.00	9.23	9.46	9.68	9.90	10.11	10.32
2¼	6.58	6.75	6.91	7.08	7.23	7.39	7.54	7.68	7.97	8.25	8.52	8.78	9.03	9.28	9.52	9.75	9.98	10.21	10.42	10.63
2⅜	6.78	6.96	7.13	7.29	7.45	7.61	7.76	7.91	8.21	8.49	8.77	9.03	9.29	9.55	9.79	10.03	10.26	10.49	10.72	10.94
2½	6.98	7.16	7.33	7.50	7.66	7.82	7.98	8.14	8.44	8.73	9.01	9.29	9.55	9.81	10.05	10.31	10.55	10.78	11.01	11.24
2⅝	7.18	7.36	7.53	7.71	7.88	8.04	8.20	8.36	8.67	8.97	9.25	9.53	9.80	10.07	10.33	10.58	10.82	11.06	11.30	11.53
2¾	7.37	7.55	7.73	7.91	8.08	8.25	8.41	8.58	8.89	9.20	9.49	9.78	10.05	10.32	10.59	10.84	11.09	11.33	11.58	11.81
2⅞	7.56	7.75	7.93	8.11	8.29	8.46	8.62	8.79	9.11	9.42	9.72	10.01	10.29	10.57	10.84	11.11	11.35	11.61	11.85	12.09
3	7.75	7.94	8.12	8.30	8.48	8.66	8.83	9.00	9.33	9.64	9.95	10.25	10.53	10.82	11.09	11.33	11.62	11.87	12.12	12.37
3⅛	7.93	8.12	8.31	8.50	8.68	8.86	9.03	9.20	9.54	9.86	10.17	10.48	10.77	11.06	11.34	11.61	11.83	12.13	12.39	12.64
3¼	8.11	8.31	8.50	8.69	8.88	9.06	9.23	9.41	9.75	10.08	10.40	10.70	11.00	11.29	11.58	11.86	12.13	12.39	12.65	12.90
3⅜	8.29	8.49	8.69	8.88	9.07	9.25	9.43	9.61	9.96	10.29	10.61	10.93	11.23	11.53	11.82	12.10	12.37	12.64	12.91	13.17
3½	8.47	8.68	8.87	9.06	9.26	9.45	9.63	9.81	10.16	10.50	10.83	11.15	11.46	11.76	12.05	12.34	12.62	12.89	13.16	13.43
3⅝	8.65	8.85	9.06	9.25	9.45	9.64	9.82	10.00	10.36	10.71	11.04	11.36	11.68	11.98	12.28	12.57	12.86	13.14	13.41	13.68
3¾	8.82	9.03	9.23	9.44	9.63	9.82	10.01	10.20	10.56	10.91	11.25	11.58	11.90	12.21	12.51	12.80	13.09	13.37	13.65	13.93
3⅞	8.99	9.20	9.41	9.61	9.82	10.01	10.20	10.39	10.76	11.11	11.45	11.79	12.11	12.43	12.74	13.04	13.33	13.62	13.90	14.18
4	9.16	9.38	9.59	9.79	10.00	10.20	10.39	10.58	10.95	11.31	11.66	12.00	12.33	12.65	12.96	13.26	13.56	13.85	14.14	14.42
4⅛	9.33	9.55	9.76	9.97	10.18	10.38	10.57	10.76	11.14	11.51	11.86	12.20	12.54	12.86	13.18	13.49	13.79	14.09	14.38	14.66
4¼	9.50	9.72	9.94	10.15	10.35	10.56	10.76	10.95	11.33	11.71	12.06	12.41	12.75	13.07	13.40	13.72	14.02	14.32	14.61	14.90
4⅜	9.67	9.89	10.11	10.32	10.53	10.74	10.94	11.14	11.52	11.90	12.26	12.61	12.95	13.29	13.61	13.93	14.24	14.54	14.84	15.13
4½	9.83	10.06	10.28	10.50	10.71	10.92	11.12	11.32	11.71	12.09	12.45	12.81	13.16	13.50	13.82	14.15	14.45	14.77	15.07	15.37

APPROXIMATE BLANK DIAMETERS FOR CYLINDRICAL SHELLS.—(*Continued*)

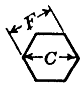
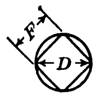
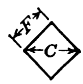
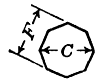
Diameter of shell, in.	Height of shell, in. 4¼	4½	4¾	5	5¼	5½	5¾	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12
4⅝	10.00	10.22	10.45	10.67	10.88	11.09	11.30	11.50	11.90	12.28	12.65	13.01	13.36	13.70	14.04	14.36	14.68	14.99	15.30	15.60
4¾	10.16	10.39	10.62	10.84	11.05	11.27	11.47	11.68	12.08	12.47	12.84	13.21	13.56	13.91	14.25	14.57	14.90	15.22	15.52	15.83
4⅞	10.32	10.55	10.78	11.01	11.23	11.44	11.65	11.86	12.26	12.65	13.03	13.41	13.76	14.11	14.45	14.79	15.11	15.43	15.74	16.05
5	10.48	10.72	10.95	11.18	11.40	11.61	11.83	12.04	12.45	12.84	13.23	13.60	13.96	14.32	14.66	15.00	15.33	15.65	15.97	16.28
5⅛	10.65	10.88	11.12	11.34	11.57	11.79	12.00	12.21	12.63	13.03	13.41	13.79	14.16	14.52	14.86	15.21	15.54	15.87	16.19	16.50
5¼	10.80	11.04	11.28	11.51	11.74	11.96	12.17	12.39	12.81	13.21	13.60	13.98	14.35	14.71	15.07	15.41	15.75	16.08	16.40	16.72
5⅜	10.96	11.20	11.44	11.68	11.90	12.13	12.35	12.56	12.98	13.39	13.79	14.17	14.54	14.91	15.27	15.61	15.95	16.29	16.61	16.93
5½	11.12	11.36	11.60	11.84	12.07	12.29	12.52	12.73	13.16	13.57	13.97	14.36	14.73	15.11	15.47	15.82	16.16	16.50	16.83	17.15
5⅝	11.28	11.52	11.76	12.00	12.23	12.46	12.69	12.90	13.33	13.75	14.15	14.54	14.93	15.30	15.66	16.02	16.36	16.70	17.04	17.36
5¾	11.43	11.68	11.92	12.16	12.40	12.63	12.85	13.07	13.51	13.93	14.33	14.73	15.11	15.49	15.86	16.21	16.57	16.91	17.25	17.58
5⅞	11.59	11.84	12.08	12.32	12.56	12.79	13.02	13.24	13.68	14.10	14.51	14.91	15.30	15.68	16.05	16.42	16.77	17.11	17.45	17.79
6	11.74	12.00	12.24	12.48	12.72	12.96	13.19	13.41	13.85	14.28	14.69	15.10	15.49	15.87	16.24	16.61	16.97	17.32	17.66	18.00
6¼	12.05	12.31	12.56	12.80	13.05	13.28	13.52	13.74	14.19	14.63	15.05	15.46	15.86	16.25	16.63	17.00	17.36	17.72	18.07	18.41
6½	12.36	12.62	12.87	13.12	13.37	13.61	13.85	14.08	14.53	14.97	15.40	15.82	16.22	16.62	17.00	17.38	17.75	18.11	18.47	18.82
6¾	12.66	12.92	13.18	13.43	13.68	13.93	14.17	14.40	14.86	15.31	15.75	16.17	16.58	16.98	17.38	17.76	18.14	18.50	18.87	19.22
7	12.96	13.23	13.49	13.74	14.00	14.24	14.49	14.73	15.19	15.65	16.09	16.52	16.94	17.34	17.74	18.13	18.52	18.89	19.26	19.62
7¼	13.25	13.52	13.79	14.05	14.31	14.56	14.80	15.05	15.52	15.98	16.43	16.86	17.29	17.70	18.11	18.51	18.89	19.27	19.64	20.01
7½	13.55	13.82	14.09	14.36	14.62	14.87	15.12	15.37	15.85	16.31	16.77	17.21	17.64	18.06	18.47	18.87	19.26	19.65	20.03	20.40
7¾	13.84	14.12	14.39	14.66	14.92	15.18	15.43	15.68	16.17	16.64	17.10	17.55	17.98	18.41	18.82	19.23	19.63	20.02	20.40	20.78
8	14.14	14.42	14.69	14.96	15.23	15.49	15.74	15.99	16.49	16.97	17.43	17.88	18.33	18.76	19.18	19.59	19.99	20.39	20.78	21.16
8¼	14.43	14.71	14.99	15.26	15.53	15.79	16.05	16.31	16.80	17.29	17.76	18.22	18.66	19.10	19.53	19.95	20.36	20.76	21.15	21.54
8½	14.72	15.00	15.28	15.56	15.83	16.10	16.36	16.62	17.12	17.61	18.09	18.55	19.00	19.44	19.88	20.30	20.71	21.11	21.51	21.91
8¾	15.00	15.29	15.58	15.86	16.13	16.40	16.66	16.92	17.43	17.93	18.41	18.88	19.34	19.78	20.22	20.65	21.07	21.48	21.88	22.28
9	15.29	15.58	15.87	16.15	16.43	16.70	16.97	17.23	17.74	18.24	18.73	19.20	19.67	20.12	20.56	21.00	21.42	21.84	22.24	22.64
9¼	15.58	15.87	16.16	16.44	16.72	17.00	17.26	17.53	18.05	18.56	19.05	19.53	20.00	20.45	20.90	21.34	21.77	22.19	22.60	23.00
9½	15.86	16.16	16.45	16.74	17.02	17.29	17.57	17.83	18.36	18.87	19.37	19.85	20.32	20.79	21.24	21.68	22.11	22.54	22.96	23.37
9¾	16.14	16.44	16.74	17.03	17.31	17.59	17.86	18.14	18.66	19.18	19.68	20.17	20.65	21.12	21.57	22.02	22.46	22.89	23.31	23.72
10	16.43	16.73	17.02	17.31	17.60	17.88	18.15	18.43	18.97	19.49	20.00	20.49	20.97	21.44	21.90	22.36	22.80	23.24	23.66	24.08
10¼	16.71	17.01	17.31	17.60	17.89	18.18	18.46	18.73	19.27	19.80	20.31	20.81	21.29	21.77	22.23	22.69	23.14	23.58	24.01	24.43
10½	16.99	17.29	17.59	17.89	18.18	18.47	18.75	19.03	19.57	20.10	20.62	21.12	21.61	22.09	22.56	23.02	23.47	23.92	24.35	24.78
10¾	17.27	17.58	17.88	18.18	18.47	18.76	19.04	19.32	19.87	20.40	20.93	21.43	21.93	22.41	22.89	23.35	23.81	24.25	25.69	25.13
11	17.55	17.86	18.16	18.46	18.76	19.05	19.33	19.62	20.17	20.71	21.23	21.74	22.24	22.73	23.21	23.68	24.14	24.59	25.04	25.47
11¼	17.81	18.12	18.44	18.74	19.03	19.33	19.62	19.90	20.46	21.01	21.54	22.05	22.55	23.06	23.54	24.00	24.47	24.92	25.37	25.82
11½	18.09	18.41	18.71	19.02	19.32	19.63	19.92	20.20	20.76	21.30	21.84	22.36	22.87	23.36	23.85	24.33	24.80	25.25	25.70	26.15
11¾	18.38	18.70	19.01	19.32	19.61	19.90	20.21	20.50	21.05	21.61	22.14	22.67	23.18	23.68	24.17	24.66	25.13	25.58	26.04	26.49
12	18.64	18.97	19.28	19.59	19.89	20.20	20.49	20.77	21.35	21.90	22.45	22.97	23.50	23.99	24.48	24.97	25.45	25.93	26.37	26.84

SCREW GAGE DIAMETERS FOR MACHINE AND WOOD SCREWS IN DECIMAL PARTS OF AN INCH

No. of screw gage	Size of number in decimals			No. of screw gage	Size of number in decimals		
	American Screw Co. standard	A.S.M.E. basic and maximum outside diameter	British Association standard (47½ deg.)		American Screw Co. standard	A.S.M.E. basic and maximum outside diameter	British Association standard (47½ deg.)
000	0.03152			11	0.20260		0.0591
00	0.04468			12	0.21576	0.216	0.0511
0	0.05784	0.060	0.2362	13	0.22892		0.0472
1	0.07100	0.073	0.2087	14	0.24208	0.242	0.0394
2	0.08416	0.086	0.1850	15	0.25524		0.0354
3	0.09732	0.099	0.1614	16	0.26840	0.268	0.0311
4	0.11048	0.112	0.1417	17	0.28156		
5	0.12364	0.125	0.1260	18	0.29472	0.294	
6	0.13680	0.138	0.1102	19	0.30788		
7	0.14996	0.151	0.0984	20	0.32104	0.320	
8	0.16312	0.164	0.0866				
9	0.17628	0.177	0.0748				
10	0.18944	0.190	0.0669				

The difference between consecutive sizes is 0.01316 in. for American Screw Co. standard and 0.013 in. for the A.S.M.E. standard.

Distances across Corners, Hexagon, Square, and Octagon

Distance across flats				
F	Hexagon C	Diameter D	Square C	Octagon C
1/4	0.2886	0.330	0.3535	0.2706
5/16	0.3608	0.410	0.4419	0.3382
3/8	0.4329	0.500	0.5303	0.4059
7/16	0.5051	0.580	0.6187	0.4735
1/2	0.5773	0.660	0.7071	0.5412
9/16	0.6494	0.750	0.7955	0.6088
5/8	0.7216	0.830	0.8839	0.6765
11/16	0.7937	0.910	0.9723	0.7442
3/4	0.8659	1.000	1.0606	0.8118
13/16	0.9380	1.080	1.1490	0.8794
7/8	1.0102	1.160	1.2374	0.9471
15/16	1.0824	1.250	1.3258	1.0147
1	1.1547	1.330	1.4142	1.0824
1 1/16	1.2268	1.420	1.5026	1.1500
1 1/8	1.2990	1.500	1.5910	1.2177
1 3/16	1.3712	1.580	1.6793	1.2853
1 1/4	1.4434	1.660	1.7677	1.3530
1 5/16	1.5155	1.750	1.8561	1.4206
1 3/8	1.5877	1.830	1.9445	1.4883
1 7/16	1.6598	1.920	2.0329	1.5559
1 1/2	1.7320	2.000	2.1213	1.6236
1 9/16	1.8042	2.080	2.2097	1.6912
1 5/8	1.8764	2.160	2.2981	1.7589
1 11/16	1.9485	2.250	2.3865	1.8266
1 3/4	2.0207	2.330	2.4708	1.8942
1 13/16	2.0929	2.420	2.5632	1.9618
1 7/8	2.1650	2.500	2.6516	2.0295
1 15/16	2.2372	2.580	2.7400	2.0971
2	2.3094	2.660	2.8284	2.1648

For a hexagon, $C = 1.1547 \times F$. $F = 0.86603 \times C$
For a square, $C = 1.4142 \times F$. $F = 0.70711 \times C$
For an octagon, $C = 1.0824 \times F$. $F = 0.92388 \times C$

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